Road and Rail Noise: Effects on Housing

Aussi disponible en français
sous le titre de
Le bruit du trafic routier et ferroviaire: ses effets sur l'habitation

Prepared by the Technical Research Division of CMHC in cooperation with the Division of Building Research of National Research Council of Canada

Canada Mortgage and Housing Corporation

Société canadienne d'hypothèques et de logement

First published 1977
Revised 1981
Reprinted 1986

Printed in Canada

ISBN 0-662-11021-0
Cat. No. NH15-27/1981 E

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NOTE: A detailed Table of Contents is attached to each of the above Parts.

Organization of Document

Each Part is organized to cover an entire subject with a minimum of cross-referencing to other Parts or publications. To achieve this, some overlapping and repetition has been necessary.

Depending on local circumstances, one or more Parts will have to be studied in order to determine the recommended solutions.

Acknowledgments

This revision was prepared by the Technical Research Division of CMHC in cooperation with J.D. Quirt and R.E. Halliwell, Division of Building Research, National Research Council of Canada.

All phases of the project were supervised by a CMHC management committee : Arthur Walton, Project Manager.

INTRODUCTION

1. Public Concern

The inconveniences caused by urban traffic noise are fast being recognized by growing numbers of the general public. Social surveys from various parts of the world indicate that the noise from surface traffic gives rise to more neighbourhood dissatisfaction than aircraft noise does. One reason for this is that surface traffic noise is not restricted to specific areas, as aircraft noise is, but pervades most built-up areas in towns and cities.

2. Canadian Action

All three levels of government have responsibilities in noise abatement. The federal government is responsible for the abatement of aircraft and industrial noise, and sets noise standards for all manufactured goods.

Provinces deal with highway noise abatement and share responsibility for industrial noise abatement with the federal government. Various highway traffic acts concern the noise produced by horns, faulty mufflers and squealing brakes.

In addition, provincial governments authorize municipalities to create anti-noise by-laws but such legislation is extremely varied among communities.

Nuisance by-laws which prohibit "loud, unusual or disturbing sounds in a neighbourhood" are difficult to enforce because of their subjective nature. Where the by-laws establish quantitative decibel limits for specific offensive noises, it is difficult to obtain noise measurements for traffic, which are defensible in court.

Existing legislation is concerned with noise made by individuals and not the total noise produced by a stream of traffic.

3. CMHC's General Policy

As a matter of general policy, Canada Mortgage and Housing Corporation wishes to draw attention to problems associated with noise from road and rail traffic; to support methods which seek to protect residential areas from the effects of such noise; to encourage the cooperation of all levels of government to develop ways of alleviating the problems associated with such noise; to discourage the construction of new residential development on sites which are exposed to high levels of noise, and to introduce sound insulation in residential development on sites subject to lower levels of noise.

The Corporation has published this document to deal specifically with new residential development which may be adversely affected by noise from roads and railways. It suggests methods for determining the noise level at a building site and, where it is too high, for reducing the noise to acceptable limits within the various parts of the building where it occurs. It is hoped that developers and all levels of government will take into consideration the criteria established in this document when preparing comprehensive land-use plans.

4. CMHC's Involvement

The Corporation's involvement is related to the security of its financing and to the quality of housing conditions encouraged by its financial support.

4.1 Market Housing

Builders should be aware that this document is advisory in nature. There are no mandatory requirements to obtain NHA insurance.

4.2 Social Housing

For public, non-profit and cooperative housing, where CMHC is providing either direct financing or subsidies, the Corporation has decided to use a number of the recommendations set out in this document as mandatory standards. For these social housing projects, the following policies are applicable:

4.2.1

- The Corporation will apply the following policy in relation to the categories detailed in Part 1, Section D.

4.2.1.1

- In the upper zone, where the noise level exceeds 75 dB, social housing projects shall be denied financing under the National Housing Act

4.2.1.2

- In the intermediate zone, where the noise level is between 55 dB and 75 dB, the social housing projects shall be denied financing under the National Housing Act, unless adequate sound insulation is provided

4.2.1.3

- In the lower zone, where the noise level is below 55 dB, housing construction which meets Residential Standards 1980 will provide adequate sound insulation, and financing under the National Housing Act will be available for social housing projects

4.2.2 Adequate Sound Insulation (See Part 6, Section A)

- Where noise levels are between 55 dB and 75 dB, the Corporation recommends or requires adequate sound insulation in new dwellings and the provision of suitable outdoor amenity space with a noise level of 55 dB or less
- "Adequate sound insulation" is defined as the sound insulation provided in a dwelling unit in accordance with the Corporation policy established by the recommendations in this document
- To achieve the required noise reduction, each of the components of the outer shell, or "envelope", of a building (i.e., windows, doors and walls) must provide an appropriate degree of sound insulation
- All the appropriate components listed in Tables 6.2, 6.3 and 6.4 are the minimum acceptable to the Corporation
- The Corporation requires alternative means of ventilation (see also Appendix C)
- The Corporation recognizes that there are other and more detailed methods of calculating sound insulation. Substantiated proposals, based upon other methods, may be acceptable to the Corporation in lieu of proposals adhering strictly to the method of calculation outlined in this publication.

5. National Research Council

The Division of Building Research of the National Research Council has contributed substantially to this publication, which is based upon the best information available. Although it is hoped that the recommendations will be appropriate for several years, they will be subject to continuous review and should be updated on the advice of the National Research Council.

PART 1 — NOISE

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Section A — Noise

Introduction

Before attempting to discuss traffic noise, which is primarily a social and community problem, it might be useful to consider briefly what noise is and what its effects are.

Sound is the sensation caused by fluctuations in air pressure detected by the human ear. When that sound is unwanted by the recipient, it is described as noise.

Noise can affect people in a variety of ways, the most important of which may be damage to hearing, interference with communication or concentration, disturbance of sleep and general annoyance. Any of these factors could lessen one's efficiency and general well-being.

Reaction to the same sound intensity and source varies considerably from person to person. What may be annoying to one person might well be acceptable to another.

One's environment has a distinct bearing on what may be considered excessive noise. Factory workers may require protection against hearing loss. Noise levels in offices must allow for adequate communication or concentration, and, in the home, people are entitled to enjoy their privacy free from interfering noises.

To allow for the great variations in the reactions of individuals to noise, recommendations to deal with the problems it causes have to be based on the average reaction.

It is not easy to define noise in a wholly satisfactory way but for the purpose of this document an acceptable definition is "sound which is undesired by the recipient". This simple description emphasizes the subjective nature of noise and the fact that its measurement is a matter of human values and environments.

Noise Levels

While everyone is conscious of noise, very few people have any idea of noise levels. They tend to describe them in terms of annoyance, ranging from acceptable to very annoying. Section B discusses the evaluation of traffic noises in general terms and presents some examples of the noise levels to which people are normally exposed.

Section B — Traffic Noise

Introduction

Noise from road traffic fluctuates in a more or less regular fashion throughout the day. The more distant a person is from the traffic, the lower and steadier the noise level; the closer he is, the higher the average level and the more obvious the noise peaks become. This is also true for rail traffic, which generates higher levels of a more intermittent nature. In general, road traffic noise is anonymous, coming as it does from a stream of vehicles. On the other hand, rail noise is often attributable to a specific train.

The effects of traffic noise are greater in dwelling units than in some offices and factories, where internal activities frequently generate more noise than enters from the outside. Hospitals and schools can be seriously affected by traffic noise.

Whatever improvements occur to reduce vehicle noise will take a long time and may be offset by the ever-increasing number of vehicles on the roads. Although traffic engineering recognizes noise problems, it has its own priorities and objectives and can deal with noise only in limited ways, such as the construction of berms on major highways. The architect and the planner, however, have the most effective means of improving the environment and particularly the residential environment: careful orientation of housing may easily reduce the apparent noise level.

It is important, therefore, that noise control in new buildings be considered at the planning stages.

Evaluation of Traffic Noise

The noise problem can be considered under three broad headings: source, propagation and the receiver environment. In the case of surface traffic noise, the source is traffic, made up of a varying number of vehicles of different types and the roadway or railway track on which the traffic moves. The propagation of the noise is influenced by the level of the road or track above or below the surrounding grade, the distance and shielding between the road or track and the receiver, and the type and configuration of the ground between them.

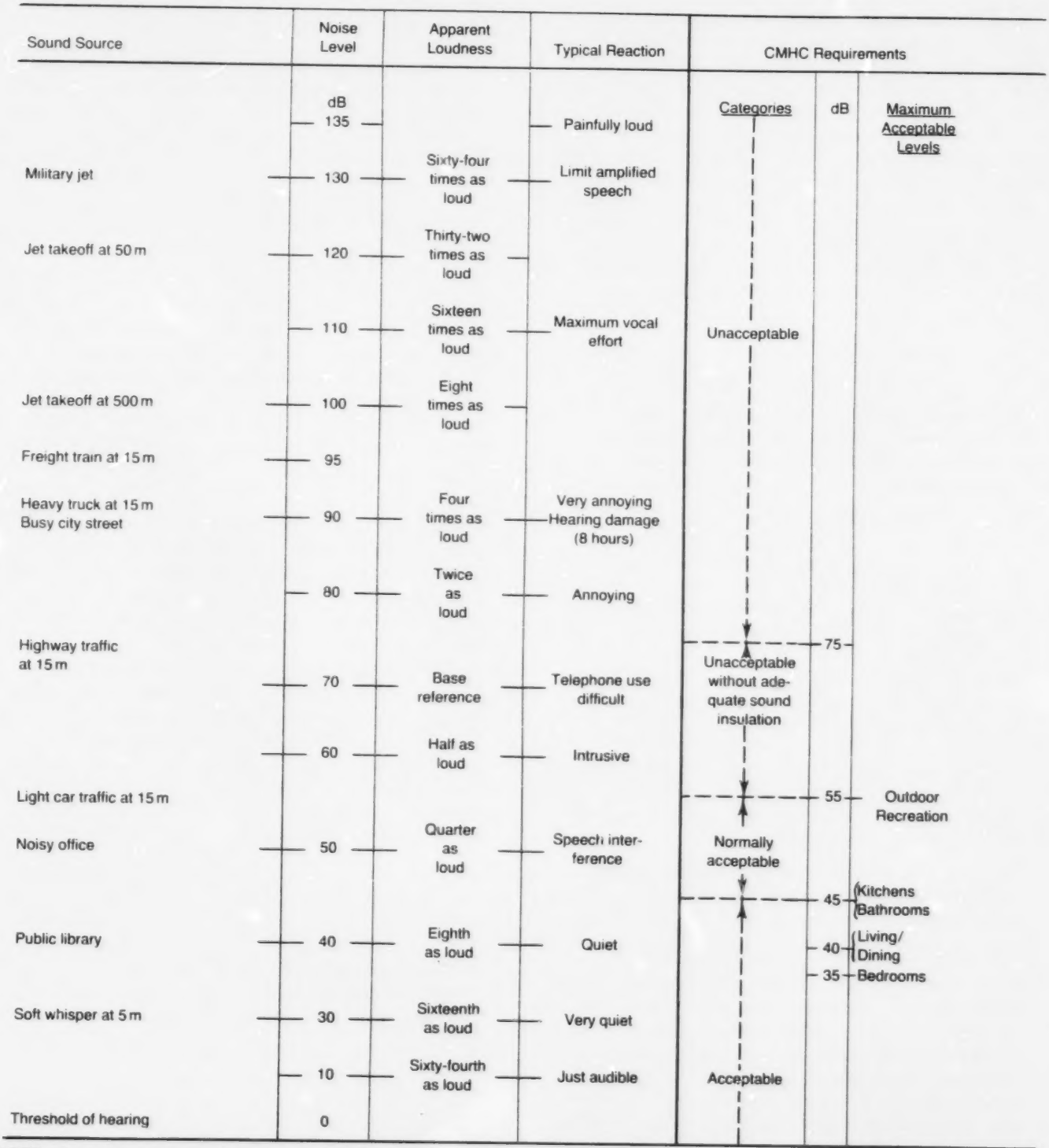
The basic physical measure of noise used in this report is the A-weighted sound level, sometimes labelled "dBA". This is an overall measurement of all components of the sound, over the full range of frequencies - with special weighting of the middle frequencies - to stimulate the way the human ear responds to sounds of different frequencies. The A-weighted level has been found to correlate well with people's judgement of the loudness or annoyance of many kinds of noise, including road and rail traffic. A rough rule-of-thumb is that an increase of 10 dB in sound level doubles the apparent loudness.

It should be noted that aircraft noise is usually described in somewhat different terms. However, the procedures presented for specifying sound insulation of houses near airports* are essentially the same as those described here.

There are two basic types of identifiable intruding noise which increase the outdoor noise level above the background level: steady or semi-steady, constant noises, and intermittent, single, unrelated noises. The background noise level is that which remains after all identifiable traffic noises have been eliminated.

* *New Housing and Airport Noise*, NHA 5185/81/05, Canada Mortgage and Housing Corporation, Revised 1981.

Fig. 1 — Common noise levels and typical reactions



NOTE: The minimum difference in noise level noticeable to the human listener is 3 dBA 10 dB increase in level appears to double the loudness, while a 10 dB decrease halves the apparent loudness.

Section C — Recommended Levels of Traffic Noise

The acceptance of noise depends on both the characteristics of that noise and the activities of the listeners. The activities most affected by noise fall into two categories, corresponding to two different criteria. For activities similar to speech communication (including listening to radio and television), the first requirement is that the noise level does not interfere significantly with comfortable speech communication or with listening to soft music. The other important category is sleeping: noise, especially at night, should not interfere with normal sleep patterns.

To deal with the fluctuating noise level from road or rail traffic, it is convenient to describe it in terms of the equivalent level (L_{eq}). This is the level of a steady sound having the same energy, at a given time, as the fluctuating sound. For the purposes of this document, the A-weighted 24-hour equivalent sound level is used as the basic noise descriptor. This noise measure has been extensively tested in numerous social surveys. Of the commonly used noise descriptors, it is among the easiest to measure or to predict accurately, and no other descriptor has been shown to provide a significantly better prediction of the community response to noise.

Hereafter "noise level" expressed in decibels (dB) should be taken to mean the A-weighted 24-hour equivalent sound level.

The maximum equivalent level that will not impair sustained conversational speech is 40 dB. Noise above this level causes people to raise their voices and therefore is not acceptable for a quiet indoor environment. In order to hear quieter passages of music, a level of about 35 dB would be preferred. Communication in a slightly raised voice is acceptable in kitchens and bathrooms and usually in outdoor recreation areas.

Sleep arousal and interference with going to sleep depend on the level of noise and on the fluctuations in level or character that occur. A useful criterion is that the maximum levels should not exceed the indoor background level by more than about 5 dB. Quiet interior levels range from 25 to 35 dB. Normally night-time traffic is less than day-time traffic and the 24-hour average level provides a fair measure of maximum night-time levels. The maximum level acceptable in bedrooms is 35 dB.

Outdoor noise levels should be considered as well as indoor because residential areas ought to include some space for outdoor recreation, such as patios, balconies and play areas. Experience indicates that somewhat higher noise levels are generally more acceptable outside than inside. An appropriate outdoor noise level is 55 dB, which would correspond typically to an indoor level of 40 dB. These levels would permit conversation at close range or in a slightly raised voice most of the time. Such background noise may serve the purpose of masking more specific sounds, such as conversation on a neighbour's patio.

To meet these various criteria of acceptable noise levels, the levels given in Table 1 are recommended:

Table 1

Maximum acceptable levels of road and rail traffic noise in dwellings and in outdoor recreation areas.

Room	Noise Level
Bedrooms.....	35 dB
Living, dining, recreation rooms.....	40 dB
Kitchens, bathrooms, hallways, utility rooms.....	45 dB
Outdoor recreation area.....	55 dB

Note:

In downtown apartment projects where, because of site restrictions, adequate noise reduction measures are not always possible, it is recognized that noise levels above 55 dB do not make open space completely ineligible for inclusion as amenity space. To provide a flexible approach, a sliding scale may be used in which for each 2 dB over the acceptable limit, 10% of the area of a balcony or other open space is ineligible, e.g., a balcony of 30 m^2 with a level of 61 dB would have 21 m^2 eligible amenity area; at 65 dB the eligible area would be 15 m^2.

In an ordinary dwelling complying with Residential Standards, the indoor noise level should be at least 20 dB below the outdoor level when windows are closed. If the outdoor noise level is not more than 55 dB, then all the proposed requirements could normally be met if the construction complies with Residential Standards, although it might still be prudent to locate bedrooms on the quieter side of the building.

In noisier locations, some shelter is needed for outdoor recreational space so that it meets the 55 dB requirements. The shelter might take the form of a barrier wall, solid fence, or berm between the road and the recreational space. In some layouts, the building itself, row housing for example, may form an adequate barrier to protect outdoor space on the sheltered side. Generally, however, a reduction of 20 dB is the maximum that can be expected from a barrier. It follows that outdoor space which is quiet enough cannot be achieved at sites where the noise level is greater than 75 dB.

Section D — Classification of Areas Adjacent to Roads and Railways

Introduction

Statistical analyses of sociological surveys indicate that residents judge their living conditions in four distinct ways: convenience; attractiveness; intrusion of objectionable features, such as noise; and ease of movement into and out of the neighbourhood. People's reaction to noise may therefore be tempered by these other considerations.

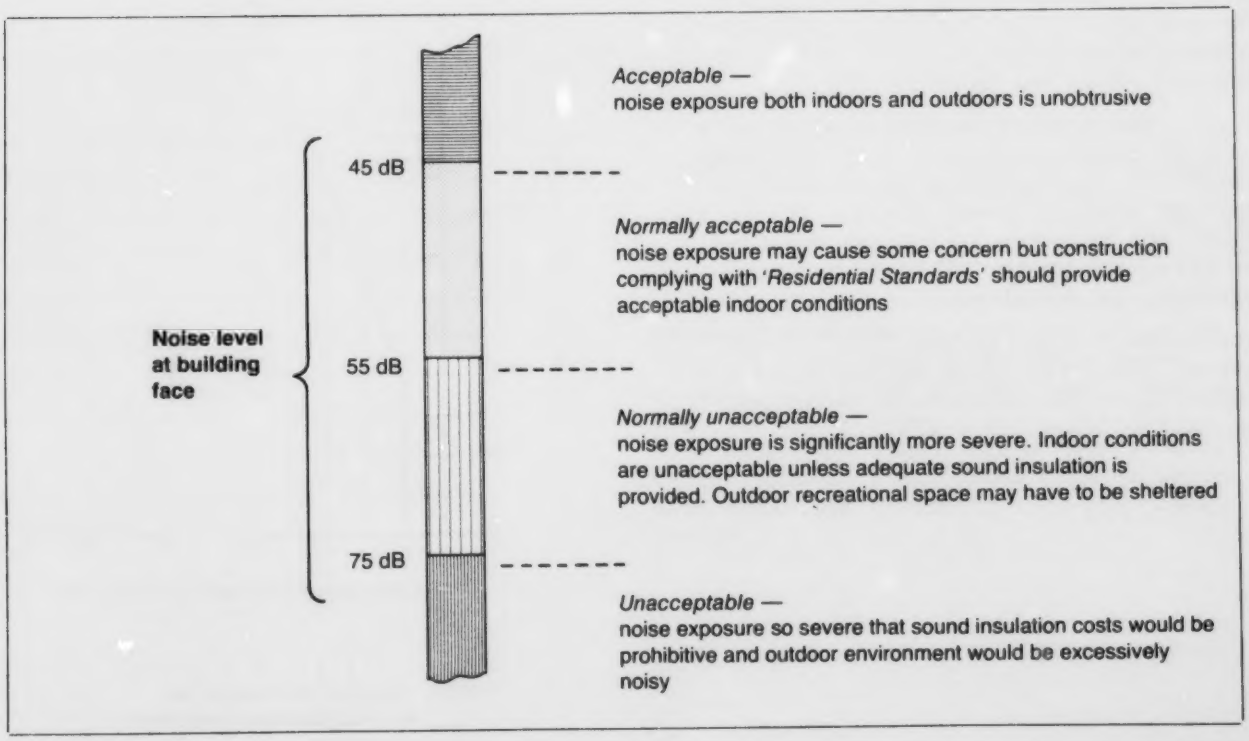
Hence, residential areas adjacent to roads and railways cannot be classified strictly according to people's reactions, except in statistical terms.

Identification of Areas

In order to apply the available noise abatement information to the assessment of noise exposure at a site, the categories listed below are recommended.

Normal construction in new residential buildings complying with Residential Standards should provide an acceptable indoor environment up to an outdoor noise level of 55 dB. Above this level there is an ever-increasing likelihood that normal construction will be unable to provide adequate sound insulation.

An analysis of available information indicates that residential development with adequate sound insulation could be allowed up to a noise level of 75 dB. Above this, the annoyance caused by road and rail traffic so seriously affects the environment that residential development should not be considered.


Noise level at building face
45 dB
55 dB
75 dB
Acceptable — noise exposure both indoors and outdoors is unobtrusive
Normally acceptable — noise exposure may cause some concern but construction complying with 'Residential Standards' should provide acceptable indoor conditions
Normally unacceptable — noise exposure is significantly more severe. Indoor conditions are unacceptable unless adequate sound insulation is provided. Outdoor recreational space may have to be sheltered
Unacceptable — noise exposure so severe that sound insulation costs would be prohibitive and outdoor environment would be excessively noisy

In relation to these categories, CMHC considers the following applications appropriate:

a) the upper zone, where the noise level exceeds 75 dB, is unsuitable for housing

b) the intermediate zone, between 55 dB and 75 dB, is unsuitable for housing unless adequate sound insulation is provided

c) in the lower zone, where the noise level is below 55 dB, housing construction meeting Residential Standards will provide adequate sound insulation.

Cautionary Note:

Caution should be exercised when building within 100 m of a railway line. At this distance there is a possibility of high vibration levels within the building due to both ground vibration and airborne noise. In such situation it is recommended that heavyweight construction be used and that a qualified person be consulted on other forms of vibration control which may be necessary.

Note: The noise from road traffic at a site is directly related to any combination of the following conditions: average vehicle speed, density of traffic flow, the proportion of heavy vehicles to cars, the number of lanes and the distance to the site.

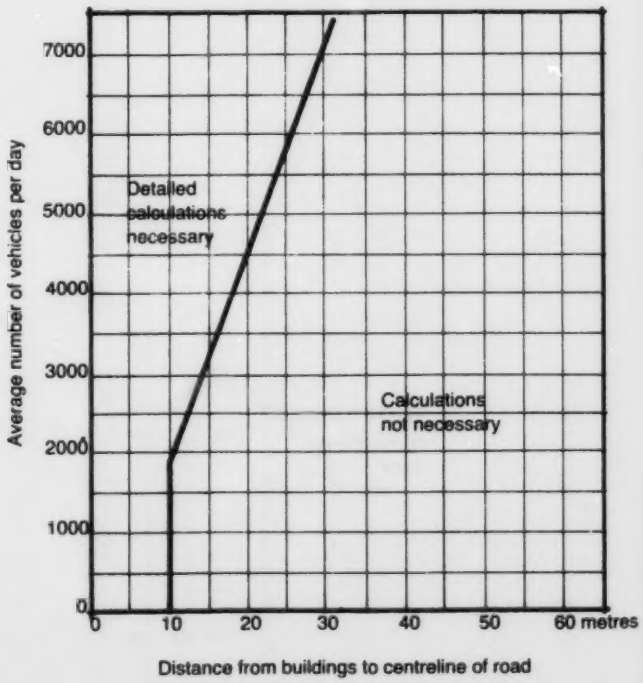
Therefore, it is not practical to use street classifications to establish the suitability for residential development of land adjacent to roads.

Need for Detailed Calculations

Even taking account of the problems and difficulties previously mentioned, it is possible to build housing near roads and railways and achieve reasonable interior noise levels, provided that proper measures are taken to ensure that the sound insulation is adequate.

For roads where the speed limit is 50 km/h or less and heavy vehicle traffic is negligible (i.e., restricted to normal residential delivery), it is possible to determine whether the site is acceptable without further reference to the detailed sections of this document. Figure 2 is used for this purpose.

Fig. 2 — Need for detailed calculations



NOTE: For speeds of 50 km/h or less, and negligible heavy vehicle traffic

PART 2 — GENERAL PRINCIPLES OF NOISE CONTROL

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General Principles

Site Selection
Orientation of Buildings
Internal Layout
Primary Agents of Sound Transmission
Insulation

General Principles

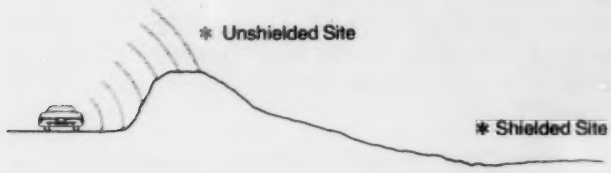
Subsequent sections of this guide deal in detail with traffic noise problems, acceptable levels of noise, the classification of areas, the prediction of noise levels, and so on.

Before discussing technical details, however, the logical way to ensure that a building has an acceptable noise environment is to examine carefully the acoustical design elements in the initial planning stages. The most important elements that should be considered are:

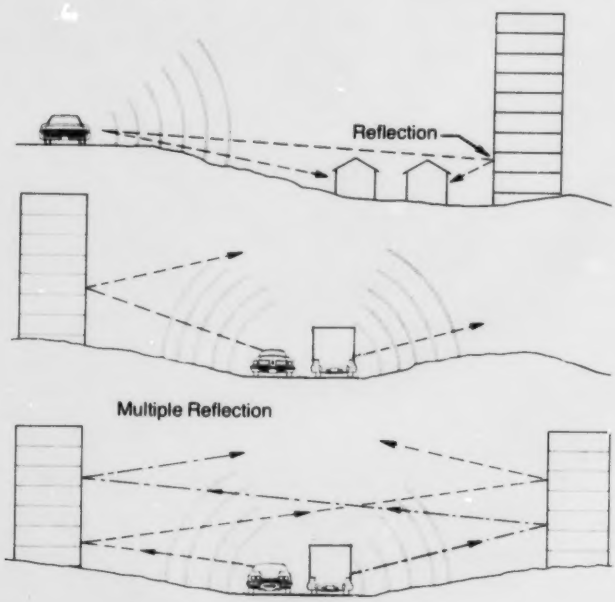
- site selection
- orientation of buildings on the site
- internal layout
- the primary agents of sound transmission.

Site Selection

- Use the natural landscape to the best advantage. Rolling or hilly terrain may provide acoustical benefits not available on a flat or hollow site.

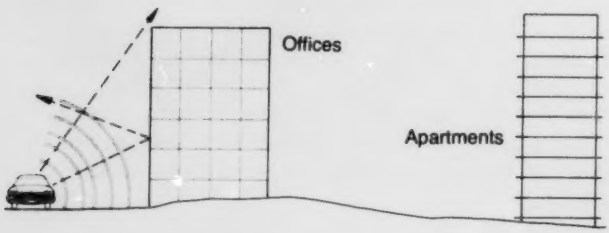


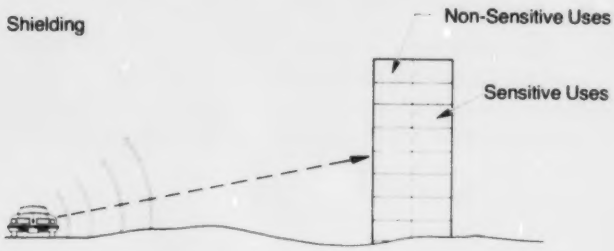
- Study the surrounding existing and proposed development which may cause adverse effects, especially where heavy volumes of traffic are involved. Zoning and future development plans for the area should be taken into account, since reflections of sound waves between opposite buildings generally increase noise levels.



• Similarly, avoid sites at busy intersections, especially where accelerating, decelerating and braking take place, and sites where more than one traffic route occurs, such as a railway running alongside a road. These sites can be extremely noisy.

If this type of site cannot be avoided, use existing buildings as noise barriers or locate non-sensitive uses on the noise side.

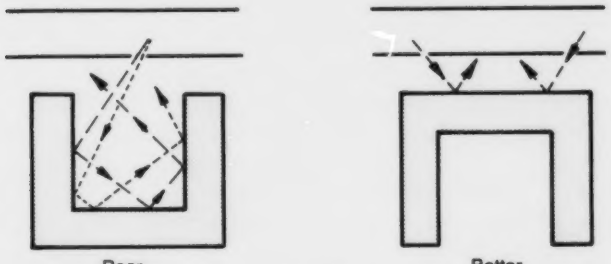




• Although no specific correction is allowed in this document for atmospheric effects, the upwind side of a traffic source is generally quieter, especially where large volumes of traffic are involved and where the distances from the source to the receiver are long.

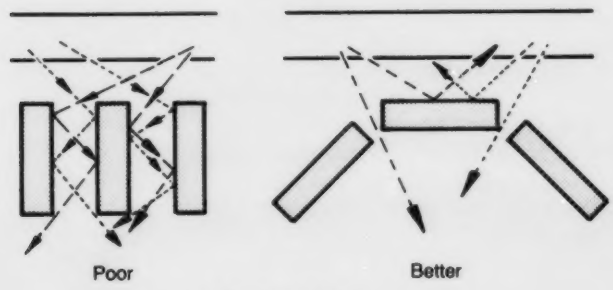
Orientation of Buildings

- Building should be located to take full advantage of any natural features or existing buildings which may provide acoustical shielding.
- Buildings should be located as far as possible from the noise source.
- Buildings should be arranged so that as many dwelling units as possible are shielded from the traffic noise.



Shielding

- Where a number of long buildings are proposed, they should not be at right angles, nor should they be parallel to one another, in order to avoid the reflection of noise between buildings.



Reflection of Noise

- Long buildings with apartments on only one face or with "through" apartments (exposed on both sides of the building) are best built parallel to the traffic route. Noise-sensitive areas, such as bedrooms, should be located on the quiet side of the building, thereby using the building itself as a noise barrier. Less noise-sensitive areas, such as storage rooms, bathrooms and kitchens, should be located on the side facing the traffic.
- Precautions must be taken that poor site planning in access and parking areas does not negate the benefits achieved by locating the buildings carefully away from traffic noise.

Internal Layout

Practical use can be made of the fact that most buildings, particularly multiple dwellings, have a "noisy" side and a "quiet" side, and their internal design can cater to these uses.

Noise-sensitive uses, such as bedrooms and dining rooms, should be located on the quiet side of the building, and non-sensitive uses, such as bathrooms and storage areas, should be on the noisy side. In some forms of multiples, therefore, it may be possible to locate non-sensitive uses such as elevators, laundry and equipment rooms, hallways and corridors, along the wall facing the traffic route. In effect, the building can then be used as a noise barrier to improve the conditions at the rear.

Primary Agents of Sound Transmission

The outer shell or envelope of a building consists of the roof, walls, doors and windows; each of these components allows some sound to pass through. Roofs built to National Building Code standards, however, provide sufficient noise reduction that they can be ignored in this guide. Solid double doors provide the best protection against excessive noise; a single hollow core provides the least. The best noise control for windows is provided by the fixed variety and their effectiveness is increased as the air space between panes and the glass thickness is increased. Wall construction depends mainly on its mass to control noise.

Insulation

Acoustical and thermal energy transfer through walls, doors and windows obey very different physical principles, so very good correlation between noise reduction and thermal transmission should not be expected. However, good acoustical performance usually implies good thermal performance.

PART 3 — ROAD TRAFFIC NOISE

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Section A — Road Traffic Noise

Introduction

Vehicular noise in cities is present in two main forms — the noise caused by heavy traffic and that caused by light vehicular movement. A heavy volume of traffic along main routes creates a high noise intensity background. Noise from heavy vehicles appears on a graph only as small peaks above the background noise. On other streets, particularly in residential areas, the lower traffic volume creates lower levels of background noise, above which the noise from all types of vehicles appears as higher peaks.

Current trends are for both these forms of noise to increase as the number of vehicles increases, as new highways are built and as suburbs spread out along existing highways. So noise is a problem in suburban and urban areas alike.

Canadian practice generally has been to minimize the movement of heavy motor vehicles on residential streets by prohibiting through traffic in residential areas or by designating mandatory truck routes. One-way street systems have also been introduced in recent years to improve the traffic flow. This often leads to increasing volumes of traffic and a deteriorating road.

Main Sources of Noise

There are two major sources of noise from moving motor vehicles: the engine-exhaust system and the tire-roadway interaction. However, a number of factors directly affect the amount of traffic noise a person hears:

- Density — as the number of vehicles increases, so does the noise level
- Composition — the greater the percentage of heavy vehicles, the greater the noise
- Speed — as traffic speed increases, so does the noise level

- Stopping and moving off — both the character and the levels of noise are affected as vehicles slow down, stop and then accelerate

- Road Gradients — the noise from vehicles, particularly the heavier ones, increases with the gradient

- Road Width — the width of the road can affect the speed and volume of traffic. The distance from the centreline of the road to a building or site and the effectiveness of any noise barriers between it and the building site are related to the width of the road easement

- Ground Surface — the noise level near the ground may be reduced by the nature of the surface over which the sound waves pass

- Road Surface — the noise generated by automobiles and trucks depends on the type of road surface and its condition. The noise level predicted in Section B is appropriate for asphalt or concrete roads in "average" condition. Because the condition of the surface of any road may vary significantly from year to year, no specific corrections for various road surfaces are used.

This section outlines a procedure for taking account of the variables discussed in Part 3 - Section A.

The basic model assumes a straight and level road on the same grade as the surrounding land and then provides a series of adjustments to take account of other situations.

Step 1 - Traffic Counts

To determine the noise generated by traffic on a particular road, the following information about the average daily traffic is required:

1. Traffic speed in kilometres per hour, taken to be the posted speed.
2. Average daily traffic volume (vehicles per 24-hour day).
3. Percentage of heavy vehicles (all vehicles with more than four wheels or a gross vehicle weight greater than 5000 kg).

Where traffic statistics are available from municipal or provincial authorities, the average daily traffic volume shall be taken to be the Annual Average Daily Traffic (AADT). In general, the highest value of AADT predicted for the next ten years should be used if it is available.

Where traffic counts or predictions are not available from provincial or municipal authorities (in the case of smaller municipalities, secondary roads, and so on), it may be necessary to estimate the traffic flow from direct observation. In such cases the observed results should be adjusted to reflect the best available estimates of seasonal variations and anticipated traffic increases.

Step 2 - Base Noise Level

Determine the base noise level at a receiving point 30 m from the centreline of the roadway. If the total width of a multi-lane road (edge of pavement to edge of pavement) is less than the distance from the midpoint to the receiver, then it is treated as one road. Wider roadways should be treated as two or more roads and their individual noise levels calculated and combined, as detailed in Part 5. Base noise levels for traffic speeds from 40 km/h to 110 km/h are given in Tables 3.1.1 to 3.1.8 for various traffic volumes and percentages of heavy vehicles.

Step 3 - Correction for Road Gradient

For road gradients of one percent or more, add the correction indicated in Table 3.2.

Step 4 - Correction for Interrupted Traffic Flow

When the free flow of traffic is interrupted by traffic lights, stop signs or corners, necessitating a halt or substantial change in speed, the noise levels increase and a correction must be made. For locations within 150 m of a traffic light or other interruptions in traffic flow, add a correction as indicated in Table 3.3.

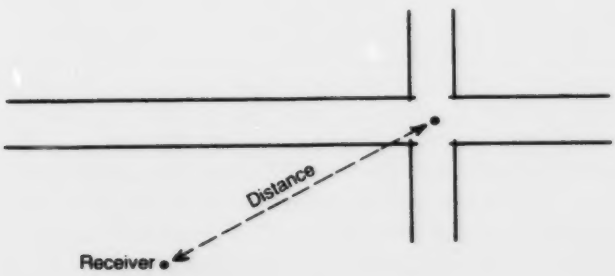
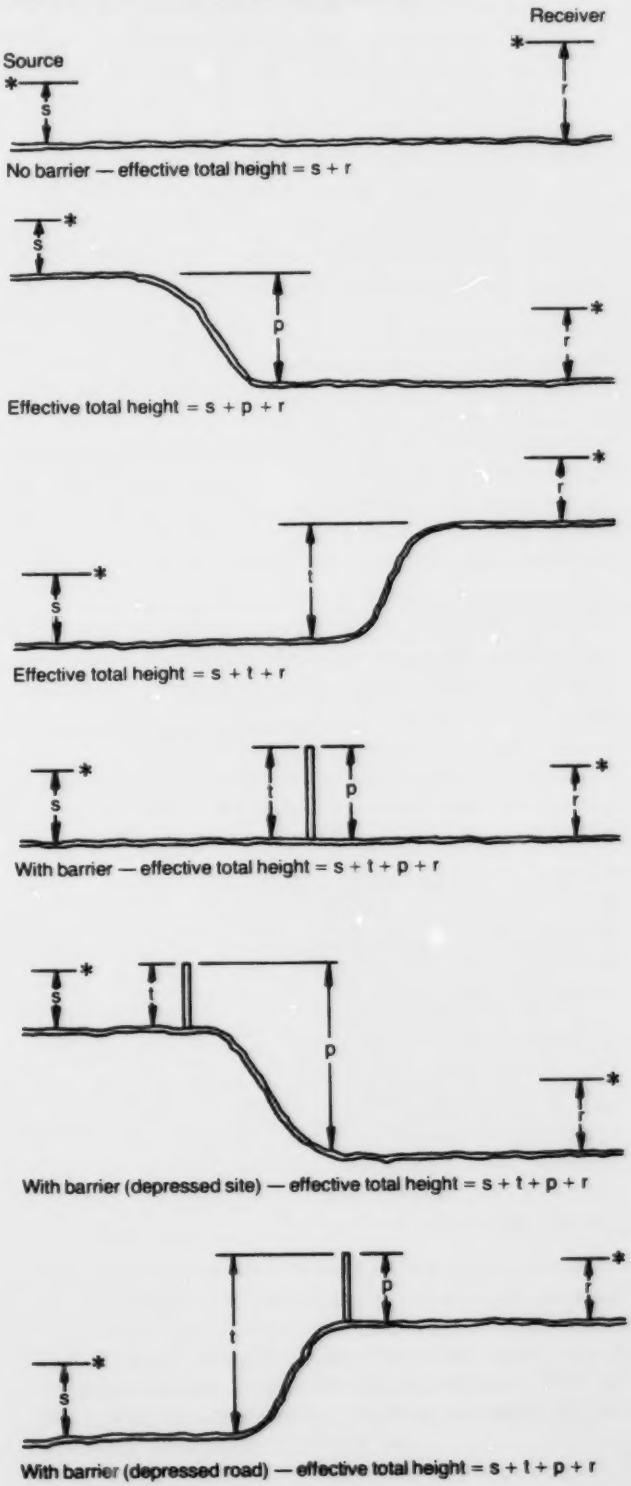


Fig. 3a — Effective total height above ground


Receiver
Source
s
r
No barrier — effective total height = s + r
p
Effective total height = s + p + r
t
Effective total height = s + t + r
With barrier — effective total height = s + t + p + r
With barrier (depressed site) — effective total height = s + t + p + r
With barrier (depressed road) — effective total height = s + t + p + r

Step 5 - Determination of Equivalent Source Height

To determine both ground attenuation and barrier attenuation (Steps 6 and 7), the source height must be established. An "equivalent source height" that takes into account the contribution of wheel noise and heavy vehicle exhaust noise is given in Table 3.4 for a range of traffic speeds and percentages of heavy vehicles.

Step 6 - Correction for Distance

The procedure up to Step 4 gives the noise levels for a receiving point 30 m from the centreline of the roadway, when the ground surface is hard. If the receiver position or the ground surface are different from this, the noise level may be higher or lower. In general, the noise level diminishes as the distance between source and receiver is increased.

An acoustically "hard" surface is one that reflects sound well. This would include such surfaces as concrete, asphalt, clay or compacted gravel. If more than half the ground surface between the source and receiver is "hard", the distance correction should be calculated, using the section of Table 3.5 for "hard" ground.

Because the distance from the source to a receiving point above or below source height is greater than the horizontal distance, lower outdoor noise levels would be expected at the upper storeys of a multi-floor building than at road level. However, this reduction in outdoor noise levels is offset by the dependence of the building's noise insulation on the angle from which sound arrives. For this reason, the distance correction is based only on the horizontal distance if the ground surface is "hard".

If more than half the surface between the source and receiver is "soft" (e.g., planted with grass, shrubbery or other dense vegetation), an extra reduction in noise will occur if the path of the sound from source to receiver is near the ground. The height of the source and receiver above the ground and the height of any intervening barrier affect the noise reduction associated with a soft surface. An "effective total height" must be calculated from the heights mentioned, using the expression given in the appropriate diagram in Fig. 3a. Then, using this effective total height and the horizontal distance, the distance correction can be calculated from the section of Table 3.5 for "soft" ground surface.

Step 7 - Correction for Barriers

The noise from traffic may be reduced by the presence of any obstruction that interrupts the line of sight between the noise source and the receiving point. (However, trees and shrubs have been found to provide very little shielding.) Note that the noise source may be considerably above the road surface, as is indicated in Table 3.4. The barrier might be a road embankment or cutting, an earth berm, one or more buildings, or a specially constructed wall. If a wall is constructed for this purpose, it must have an impervious surface with a negligible number of holes or cracks (less than 0.2 percent of the total surface area). The barrier material should weigh at least 5 kg/m^2 (10 kg/m^2 if barrier attenuation is greater than 10 dB).

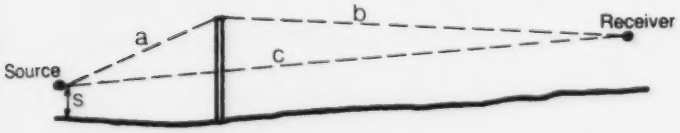
"Barrier attenuation" is the reduction in the noise level at a receiving point relative to the noise level that would exist there if the ground surface were "hard" and if nothing interrupted the path from the noise source to the receiver. Note that the correction for distance when the ground surface is "soft" also depends on the presence or absence of a barrier. Typically the addition of a barrier provides some barrier attenuation, but reduces the noise level provided by a soft ground surface. The trade-off between these two effects must be weighted in assessing the net value of a proposed barrier.

Both the height and the length of a barrier are important to its effectiveness in reducing the noise level. Therefore, both the vertical cross-section and the plan view must be considered. The procedure here first evaluates the attenuation for a barrier of "infinite length" (i.e., a barrier so long that a negligible amount of noise comes from the ends) considering only the vertical cross-section.

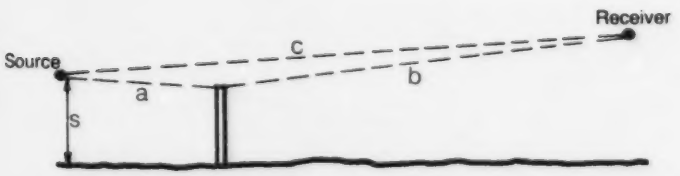
This result is then modified to allow for the barrier's length and its location relative to the road (as shown in a plan view).

Attenuation for a Barrier of Infinite Length

The fundamental barrier geometry is illustrated by Fig. 3b, which is a vertical section along the line from the noise source to the receiving point. The distance "s" is the equivalent height of the noise source above the road surface, which is determined in Step 5.



Barrier interrupts line of sight

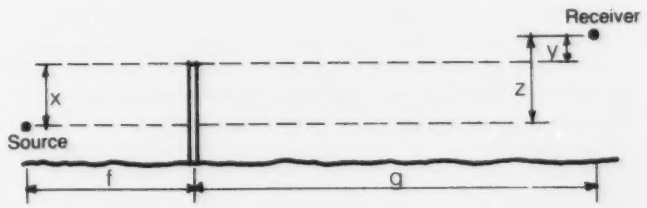


Barrier nearly interrupts line of sight

Fig. 3b — Basic barrier model (vertical section)

For a barrier of infinite length, the attenuation depends on the difference between the straight line distance (c) from source to receiver in Fig. 3b and the combined distance (a + b) from the source to the top of the barrier and then to the receiver. This is called the "path length difference".

Receiver below barrier



Receiver above barrier and source

Fig. 3c — Necessary dimensions for calculation of barrier attenuation

Calculating the path length difference is straightforward. The necessary horizontal and vertical distances are indicated in Fig. 3c for the two important cases where the barrier interrupts the line of sight and where the barrier nearly interrupts the line of sight. The distances "a", "b" and "c" may be calculated using the following expressions:

$$a = \sqrt{x^2 + f^2}$$

$$b = \sqrt{y^2 + g^2}$$

$$c = \sqrt{z^2 + (f + g)^2}$$

Note: "x" - difference in elevation between source and top of barrier.
"y" - difference in elevation between receiver and top of barrier.
"z" - difference in elevation between source and receiver.

In calculating the value of c, the horizontal distance used should be the exact sum of the two horizontal distances, and the vertical distance should be the exact sum or difference of x and y, as is indicated in Figure 3c. All the square roots should be calculated to an accuracy of 0.01 m. Note that this does not mean that this accuracy is required in the original distances, such as f and g. *(Note: inexpensive electronic calculators which can compute squares and square roots are readily available.)*

The path length difference = a + b - c. If the barrier does not interrupt the line of sight from the source to the receiver and the path length difference is 0.06 m or greater, the barrier attenuation is zero, and no further calculations are required. In other cases, the path length difference may be used with Table 3.7 to obtain the attenuation for a barrier of infinite length.

The calculations using the path length difference are appropriate for continuous barriers such as berms, specially constructed fences or row housing. However, some attenuation may also be provided by rows of detached buildings that are sufficiently closely spaced (where the average space between buildings is less than 50 percent of the average building length). For the first row of building obstruction, the line of sight between the source and the receiving point, allow a barrier attenuation of 4 dB. Further attenuation of 2 dB each may be allowed for the second, third and fourth rows respectively. If both a continuous barrier and one or more rows of buildings are present, an attenuation of 2 dB per row may be allowed for each of the first three rows of buildings interrupting the line of sight from the top of the barrier to the receiving point. The combined attenuation for the continuous barrier and the row(s) of housing may not exceed 20 dB. Note that these attenuations must be corrected for the actual length of the rows of buildings following the procedure outlined in the next Section, "Correction for Actual Barrier Length".

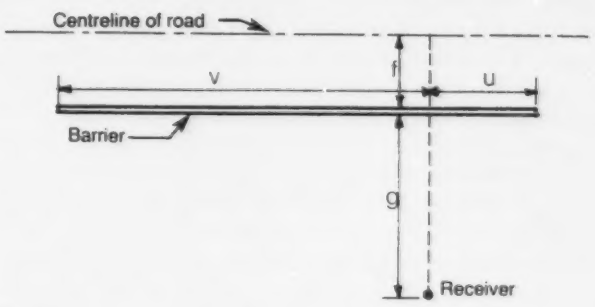


Fig. 3d — Plan view of roadside barrier

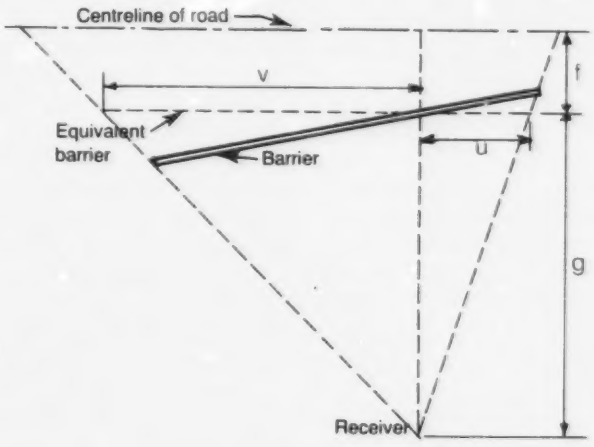


Fig. 3e — Plan view of an equivalent parallel barrier

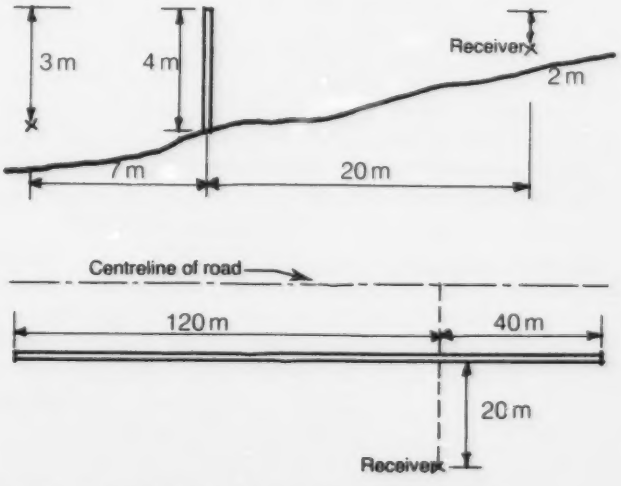


Fig. 3f — Numerical example of work procedure

Correction for Actual Barrier Length

A plan view of a barrier is shown in Fig. 3d. A line from the receiving point to the centreline of the roadway (the shortest distance to the roadway) divides the barrier into two segments, one of length v and the other of length u.

If the barrier is not parallel to the roadway, consider an equivalent barrier that is parallel to the road, as shown in Fig. 3e. The equivalent barrier is represented by the broken line parallel to the roadway and screening the same portion of the traffic.

The values of the ratios u/g and v/g are used with Table 3.6 to determine the effective barrier length ratio (w). If w is less than 10, a significant amount of noise may reach the receiving point via paths around the ends of the barrier. The value of w and the path length difference (or the attenuation for a barrier of infinite length), as determined in the section above, may be used in Table 3.7 to obtain the attenuation for the actual barrier.

Numerical Example of Work Procedure

In the example in Fig. 3f, the source is 3 m below and 7 m horizontally from the top of the barrier. The direct distance from source to barrier top is

$$a = \sqrt{(3 \times 3) + (7 \times 7)} = 7.62 \text{ m.}$$

The vertical and horizontal distance from the top of the barrier to the receiver are 2 m and 20 m respectively; the direct distance is

$$b = \sqrt{(2 \times 2) + (20 \times 20)} = 20.10 \text{ m.}$$

The receiving point is 1 m above the source and 27 m away horizontally; the direct source receiver distance is therefore

$$c = \sqrt{(1 \times 1) + (27 \times 27)} = 27.02 \text{ m.}$$

The barrier does interrupt the line of sight from the source to receiver and the path length difference is $7.62 + 20.10 - 27.02 = 0.70$ m. For a barrier of infinite length, the barrier attenuation, as given in Table 3.7, would be 13 dB.

From Fig. 3f it is seen that $u = 40$ m, $v = 120$ m and $g = 20$ m. Therefore:

$u/g = 40/20 = 2$, $v/g = 120/20 = 6$

These values can be used with Table 3.6 to obtain the effective barrier length ratio (w), which is found to be 3.

The path length difference (0.70 m) and the effective barrier length ratio ($w = 3$) can now be used in Table 3.7 to give the barrier attenuation for the actual barrier, which is 10 dB.

Further numerical examples illustrating other common barrier configurations are given in Appendix B.

Table 3.1.1 - Equivalent noise level at 30 m from centreline if posted speed limit is 40 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles												
	0.0 To 1.9	2.0 To 3.7	3.8 To 6.0	6.1 To 8.9	9.0 To 12	13 To 17	18 To 22	23 To 30	31 To 39	40 To 50	51 To 65	66 To 83	84 To 100
1000	45	46	47	48	49	50	51	52	53	54	55	56	57
1250	46	47	48	49	50	51	52	53	54	55	56	57	58
1600	47	48	49	50	51	52	53	54	55	56	57	58	59
2000	48	49	50	51	52	53	54	55	56	57	58	59	60
2500	49	50	51	52	53	54	55	56	57	58	59	60	61
3150	50	51	52	53	54	55	56	57	58	59	60	61	62
4000	51	52	53	54	55	56	57	58	59	60	61	62	63
5000	52	53	54	55	56	57	58	59	60	61	62	63	64
6300	53	54	55	56	57	58	59	60	61	62	63	64	65
8000	54	55	56	57	58	59	60	61	62	63	64	65	66
10000	55	56	57	58	59	60	61	62	63	64	65	66	67
12500	56	57	58	59	60	61	62	63	64	65	66	67	68
16000	57	58	59	60	61	62	63	64	65	66	67	68	69
20000	58	59	60	61	62	63	64	65	66	67	68	69	70
25000	59	60	61	62	63	64	65	66	67	68	69	70	71
31500	60	61	62	63	64	65	66	67	68	69	70	71	72
40000	61	62	63	64	65	66	67	68	69	70	71	72	73
50000	62	63	64	65	66	67	68	69	70	71	72	73	74
63000	63	64	65	66	67	68	69	70	71	72	73	74	75
80000	64	65	66	67	68	69	70	71	72	73	74	75	76
100000	65	66	67	68	69	70	71	72	73	74	75	76	77
125000	66	67	68	69	70	71	72	73	74	75	76	77	78
160000	67	68	69	70	71	72	73	74	75	76	77	78	79
200000	68	69	70	71	72	73	74	75	76	77	78	79	80
250000	69	70	71	72	73	74	75	76	77	78	79	80	81

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.2 - Equivalent noise level at 30 m from centreline if posted speed limit is 50 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles												
	0.0 To 1.5	1.6 To 3.5	3.6 To 6.0	6.1 To 9.2	9.3 To 13	14 To 18	19 To 24	25 To 32	33 To 42	43 To 55	56 To 71	72 To 91	92 To 100
1000	47	48	49	50	51	52	53	54	55	56	57	58	59
1250	48	49	50	51	52	53	54	55	56	57	58	59	60
1600	49	50	51	52	53	54	55	56	57	58	59	60	61
2000	50	51	52	53	54	55	56	57	58	59	60	61	62
2500	51	52	53	54	55	56	57	58	59	60	61	62	63
3150	52	53	54	55	56	57	58	59	60	61	62	63	64
4000	53	54	55	56	57	58	59	60	61	62	63	64	65
5000	54	55	56	57	58	59	60	61	62	63	64	65	66
6300	55	56	57	58	59	60	61	62	63	64	65	66	67
8000	56	57	58	59	60	61	62	63	64	65	66	67	68
10000	57	58	59	60	61	62	63	64	65	66	67	68	69
12500	58	59	60	61	62	63	64	65	66	67	68	69	70
16000	59	60	61	62	63	64	65	66	67	68	69	70	71
20000	60	61	62	63	64	65	66	67	68	69	70	71	72
25000	61	62	63	64	65	66	67	68	69	70	71	72	73
31500	62	63	64	65	66	67	68	69	70	71	72	73	74
40000	63	64	65	66	67	68	69	70	71	72	73	74	75
50000	64	65	66	67	68	69	70	71	72	73	74	75	76
63000	65	66	67	68	69	70	71	72	73	74	75	76	77
80000	66	67	68	69	70	71	72	73	74	75	76	77	78
100000	67	68	69	70	71	72	73	74	75	76	77	78	79
125000	68	69	70	71	72	73	74	75	76	77	78	79	80
160000	69	70	71	72	73	74	75	76	77	78	79	80	81
200000	70	71	72	73	74	75	76	77	78	79	80	81	82
250000	71	72	73	74	75	76	77	78	79	80	81	82	83

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.3 - Equivalent noise level at 30 m from centreline if posted speed limit is 60 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles											
	0.0 To 1.7	1.8 To 4.0	4.1 To 6.8	6.9 To 10	11 To 14	15 To 20	21 To 27	28 To 36	37 To 47	48 To 61	62 To 79	80 To 100
1000	49	50	51	52	53	54	55	56	57	58	59	60
1250	50	51	52	53	54	55	56	57	58	59	60	61
1600	51	52	53	54	55	56	57	58	59	60	61	62
2000	52	53	54	55	56	57	58	59	60	61	62	63
2500	53	54	55	56	57	58	59	60	61	62	63	64
3150	54	55	56	57	58	59	60	61	62	63	64	65
4000	55	56	57	58	59	60	61	62	63	64	65	66
5000	56	57	58	59	60	61	62	63	64	65	66	67
6300	57	58	59	60	61	62	63	64	65	66	67	68
8000	58	59	60	61	62	63	64	65	66	67	68	69
10000	59	60	61	62	63	64	65	66	67	68	69	70
12500	60	61	62	63	64	65	66	67	68	69	70	71
16000	61	62	63	64	65	66	67	68	69	70	71	72
20000	62	63	64	65	66	67	68	69	70	71	72	73
25000	63	64	65	66	67	68	69	70	71	72	73	74
31500	64	65	66	67	68	69	70	71	72	73	74	75
40000	65	66	67	68	69	70	71	72	73	74	75	76
50000	66	67	68	69	70	71	72	73	74	75	76	77
63000	67	68	69	70	71	72	73	74	75	76	77	78
80000	68	69	70	71	72	73	74	75	76	77	78	79
100000	69	70	71	72	73	74	75	76	77	78	79	80
125000	70	71	72	73	74	75	76	77	78	79	80	81
160000	71	72	73	74	75	76	77	78	79	80	81	82
200000	72	73	74	75	76	77	78	79	80	81	82	83
250000	73	74	75	76	77	78	79	80	81	82	83	84

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.4 - Equivalent noise level at 30 m from centreline if posted speed limit is 70 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles												
	0.0 To 0.6	0.7 To 2.7	2.8 To 5.5	5.6 To 8.9	9.0 To 13	14 To 18	19 To 25	26 To 34	35 To 44	45 To 58	59 To 75	76 To 97	98 To 100
1000	50	51	52	53	54	55	56	57	58	59	60	61	62
1250	51	52	53	54	55	56	57	58	59	60	61	62	63
1600	52	53	54	55	56	57	58	59	60	61	62	63	64
2000	53	54	55	56	57	58	59	60	61	62	63	64	65
2500	54	55	56	57	58	59	60	61	62	63	64	65	66
3150	55	56	57	58	59	60	61	62	63	64	65	66	67
4000	56	57	58	59	60	61	62	63	64	65	66	67	68
5000	57	58	59	60	61	62	63	64	65	66	67	68	69
6300	58	59	60	61	62	63	64	65	66	67	68	69	70
8000	59	60	61	62	63	64	65	66	67	68	69	70	71
10000	60	61	62	63	64	65	66	67	68	69	70	71	72
12500	61	62	63	64	65	66	67	68	69	70	71	72	73
16000	62	63	64	65	66	67	68	69	70	71	72	73	74
20000	63	64	65	66	67	68	69	70	71	72	73	74	75
25000	64	65	66	67	68	69	70	71	72	73	74	75	76
31500	65	66	67	68	69	70	71	72	73	74	75	76	77
40000	66	67	68	69	70	71	72	73	74	75	76	77	78
50000	67	68	69	70	71	72	73	74	75	76	77	78	79
63000	68	69	70	71	72	73	74	75	76	77	78	79	80
80000	69	70	71	72	73	74	75	76	77	78	79	80	81
100000	70	71	72	73	74	75	76	77	78	79	80	81	82
125000	71	72	73	74	75	76	77	78	79	80	81	82	83
160000	72	73	74	75	76	77	78	79	80	81	82	83	84
200000	73	74	75	76	77	78	79	80	81	82	83	84	85
250000	74	75	76	77	78	79	80	81	82	83	84	85	86

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.5 - Equivalent noise level at 30 m from centreline if posted speed limit is 80 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles											
	0.0 To 1.9	2.0 To 4.6	4.7 To 8.0	8.1 To 12	13 To 17	18 To 24	25 To 32	33 To 43	44 To 57	58 To 74	75 To 95	96 To 100
1000	52	53	54	55	56	57	58	59	60	61	62	63
1250	53	54	55	56	57	58	59	60	61	62	63	64
1600	54	55	56	57	58	59	60	61	62	63	64	65
2000	55	56	57	58	59	60	61	62	63	64	65	66
2500	56	57	58	59	60	61	62	63	64	65	66	67
3150	57	58	59	60	61	62	63	64	65	66	67	68
4000	58	59	60	61	62	63	64	65	66	67	68	69
5000	59	60	61	62	63	64	65	66	67	68	69	70
6300	60	61	62	63	64	65	66	67	68	69	70	71
8000	61	62	63	64	65	66	67	68	69	70	71	72
10000	62	63	64	65	66	67	68	69	70	71	72	73
12500	63	64	65	66	67	68	69	70	71	72	73	74
16000	64	65	66	67	68	69	70	71	72	73	74	75
20000	65	66	67	68	69	70	71	72	73	74	75	76
25000	66	67	68	69	70	71	72	73	74	75	76	77
31500	67	68	69	70	71	72	73	74	75	76	77	78
40000	68	69	70	71	72	73	74	75	76	77	78	79
50000	69	70	71	72	73	74	75	76	77	78	79	80
63000	70	71	72	73	74	75	76	77	78	79	80	81
80000	71	72	73	74	75	76	77	78	79	80	81	82
100000	72	73	74	75	76	77	78	79	80	81	82	83
125000	73	74	75	76	77	78	79	80	81	82	83	84
160000	74	75	76	77	78	79	80	81	82	83	84	85
200000	75	76	77	78	79	80	81	82	83	84	85	86
250000	76	77	78	79	80	81	82	83	84	85	86	87

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.6 - Equivalent noise level at 30 m from centreline if posted speed limit is 90 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles											
	0.0 To 1.2	1.3 To 3.8	3.9 To 6.9	7.0 To 11	12 To 16	17 To 22	23 To 30	31 To 40	41 To 53	54 To 69	70 To 89	90 To 100
1000	53	54	55	56	57	58	59	60	61	62	63	64
1250	54	55	56	57	58	59	60	61	62	63	64	65
1600	55	56	57	58	59	60	61	62	63	64	65	66
2000	56	57	58	59	60	61	62	63	64	65	66	67
2500	57	58	59	60	61	62	63	64	65	66	67	68
3150	58	59	60	61	62	63	64	65	66	67	68	69
4000	59	60	61	62	63	64	65	66	67	68	69	70
5000	60	61	62	63	64	65	66	67	68	69	70	71
6300	61	62	63	64	65	66	67	68	69	70	71	72
8000	62	63	64	65	66	67	68	69	70	71	72	73
10000	63	64	65	66	67	68	69	70	71	72	73	74
12500	64	65	66	67	68	69	70	71	72	73	74	75
16000	65	66	67	68	69	70	71	72	73	74	75	76
20000	66	67	68	69	70	71	72	73	74	75	76	77
25000	67	68	69	70	71	72	73	74	75	76	77	78
31500	68	69	70	71	72	73	74	75	76	77	78	79
40000	69	70	71	72	73	74	75	76	77	78	79	80
50000	70	71	72	73	74	75	76	77	78	79	80	81
63000	71	72	73	74	75	76	77	78	79	80	81	82
80000	72	73	74	75	76	77	78	79	80	81	82	83
100000	73	74	75	76	77	78	79	80	81	82	83	84
125000	74	75	76	77	78	79	80	81	82	83	84	85
160000	75	76	77	78	79	80	81	82	83	84	85	86
200000	76	77	78	79	80	81	82	83	84	85	86	87
250000	77	78	79	80	81	82	83	84	85	86	87	88

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.7 - Equivalent noise level at 30 m from centreline if posted speed limit is 100 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles											
	0.0 To 0.9	1.0 To 3.4	3.5 To 6.4	6.5 To 10	11 To 15	16 To 21	22 To 29	30 To 38	39 To 51	52 To 66	67 To 85	86 To 100
1000	54	55	56	57	58	59	60	61	62	63	64	65
1250	55	56	57	58	59	60	61	62	63	64	65	66
1600	56	57	58	59	60	61	62	63	64	65	66	67
2000	57	58	59	60	61	62	63	64	65	66	67	68
2500	58	59	60	61	62	63	64	65	66	67	68	69
3150	59	60	61	62	63	64	65	66	67	68	69	70
4000	60	61	62	63	64	65	66	67	68	69	70	71
5000	61	62	63	64	65	66	67	68	69	70	71	72
6300	62	63	64	65	66	67	68	69	70	71	72	73
8000	63	64	65	66	67	68	69	70	71	72	73	74
10000	64	65	66	67	68	69	70	71	72	73	74	75
12500	65	66	67	68	69	70	71	72	73	74	75	76
16000	66	67	68	69	70	71	72	73	74	75	76	77
20000	67	68	69	70	71	72	73	74	75	76	77	78
25000	68	69	70	71	72	73	74	75	76	77	78	79
31500	69	70	71	72	73	74	75	76	77	78	79	80
40000	70	71	72	73	74	75	76	77	78	79	80	81
50000	71	72	73	74	75	76	77	78	79	80	81	82
63000	72	73	74	75	76	77	78	79	80	81	82	83
80000	73	74	75	76	77	78	79	80	81	82	83	84
100000	74	75	76	77	78	79	80	81	82	83	84	85
125000	75	76	77	78	79	80	81	82	83	84	85	86
160000	76	77	78	79	80	81	82	83	84	85	86	87
200000	77	78	79	80	81	82	83	84	85	86	87	88
250000	78	79	80	81	82	83	84	85	86	87	88	89

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.1.8 - Equivalent noise level at 30 m from centreline if posted speed limit is 110 km/h

Traffic Volume (vehicles per 24 h)	Percentage of Heavy Vehicles											
	0.0 To 0.9	1.0 To 3.3	3.4 To 6.3	6.4 To 10	11 To 15	16 To 21	22 To 28	29 To 38	39 To 50	51 To 65	66 To 85	86 To 100
1000	55	56	57	58	59	60	61	62	63	64	65	66
1250	56	57	58	59	60	61	62	63	64	65	66	67
1600	57	58	59	60	61	62	63	64	65	66	67	68
2000	58	59	60	61	62	63	64	65	66	67	68	69
2500	59	60	61	62	63	64	65	66	67	68	69	70
3150	60	61	62	63	64	65	66	67	68	69	70	71
4000	61	62	63	64	65	66	67	68	69	70	71	72
5000	62	63	64	65	66	67	68	69	70	71	72	73
6300	63	64	65	66	67	68	69	70	71	72	73	74
8000	64	65	66	67	68	69	70	71	72	73	74	75
10000	65	66	67	68	69	70	71	72	73	74	75	76
12500	66	67	68	69	70	71	72	73	74	75	76	77
16000	67	68	69	70	71	72	73	74	75	76	77	78
20000	68	69	70	71	72	73	74	75	76	77	78	79
25000	69	70	71	72	73	74	75	76	77	78	79	80
31500	70	71	72	73	74	75	76	77	78	79	80	81
40000	71	72	73	74	75	76	77	78	79	80	81	82
50000	72	73	74	75	76	77	78	79	80	81	82	83
63000	73	74	75	76	77	78	79	80	81	82	83	84
80000	74	75	76	77	78	79	80	81	82	83	84	85
100000	75	76	77	78	79	80	81	82	83	84	85	86
125000	76	77	78	79	80	81	82	83	84	85	86	87
160000	77	78	79	80	81	82	83	84	85	86	87	88
200000	78	79	80	81	82	83	84	85	86	87	88	89
250000	79	80	81	82	83	84	85	86	87	88	89	90

NOTE :

1) Where actual traffic volume is not presented in the table, use the nearest listed value.

2) Values in the body of this table are A-weighted noise levels expressed in dB.

Table 3.2 - Correction (in dB) to be added for road gradient

Percentage of Heavy Vehicles	Gradient 1%	2%	3%	4%	5%
0 - 7	0	1	1	1	2
8 - 12	1	1	2	2	3
13 - 17	1	1	2	3	3
18 or over	1	2	3	3	4

Table 3.3 - Correction (in dB) to be added for interrupted traffic flow

Distance from Intersection to Receiver (metres)	Correction (in dB)
0 - 59	2
60 - 150	1
over 150	0

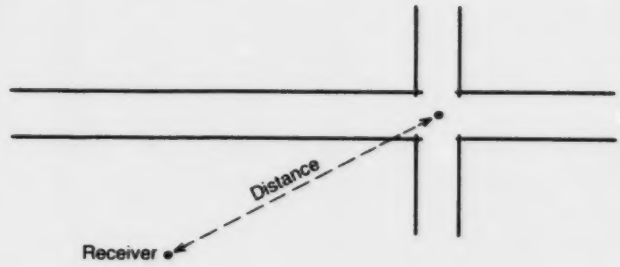


Table 3.4 - Equivalent source height (metres) for road traffic

Percentage of Heavy Vehicles	Traffic Speed km/h 40	50	60	70	80	90	100	110	
under 0.7	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	Equivalent Source Height (metres)
0.8 - 2.0	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	
2.1 - 4.0	1.1	0.8	0.7	0.6	0.5	0.5	0.4	0.4	
4.1 - 6.0	1.4	1.0	0.8	0.7	0.6	0.5	0.5	0.4	
6.1 - 8.5	1.5	1.1	0.9	0.7	0.7	0.6	0.5	0.5	
8.6 - 12.0	1.6	1.2	1.0	0.8	0.7	0.6	0.6	0.5	
13.0 - 16.0	1.7	1.3	1.1	0.9	0.8	0.7	0.6	0.6	
17.0 - 22.0	1.8	1.4	1.2	0.9	0.8	0.7	0.6	0.6	
23.0 - 50.0	1.9	1.5	1.2	1.0	0.9	0.7	0.6	0.6	
51.0 - 100.0	2.0	1.6	1.3	1.1	1.0	0.8	0.7	0.7	

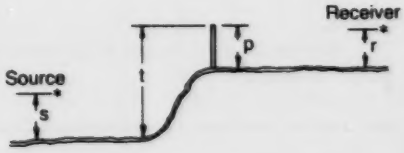
Table 3.5 - Correction (in dB) for distance from source to receiver and for total effective height above ground

Effective Total Height Above Ground (metres)	HORIZONTAL DISTANCE FROM SOURCE TO RECEIVING POINT (METRES)																	
	up to 11	11 to 14	15 to 18	19 to 22	23 to 27	28 to 35	36 to 45	46 to 57	58 to 72	73 to 90	91 to 112	113 to 142	143 to 180	181 to 225	226 to 275	276 to 350	351 to 450	451 or over
	Correction in dB if acoustically "soft" surface																	
58.0 or over	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-11	-13	-15
45.1 to 57.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8	-10	-12	-14	-16
36.1 to 45.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-9	-11	-13	-15	-17
28.1 to 36.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-8	-10	-12	-14	-16	-18
22.1 to 28.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-7	-9	-11	-13	-15	-17	-19
18.1 to 22.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-6	-8	-10	-12	-14	-16	-18	-20
14.1 to 18.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-5	-7	-9	-11	-13	-15	-17	-18	-20
11.1 to 14.0	+5	+4	+3	+2	+1	0	-1	-2	-4	-6	-8	-10	-12	-14	-16	-17	-19	-21
9.1 to 11.0	+5	+4	+3	+2	+1	0	-1	-3	-5	-7	-9	-11	-13	-15	-17	-18	-20	-21
7.1 to 9.0	+5	+4	+3	+2	+1	0	-2	-4	-6	-8	-10	-12	-14	-16	-17	-19	-20	-22
5.6 to 7.0	+5	+4	+3	+2	+1	-1	-3	-5	-7	-9	-11	-13	-14	-16	-18	-19	-20	-22
4.1 to 5.5	+5	+4	+3	+2	0	-2	-4	-6	-8	-10	-12	-14	-15	-17	-18	-20	-21	-23
2.6 to 4.0	+5	+4	+3	+1	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-19	-21	-22	-24
up to 2.5	+5	+4	+3	+1	-1	-3	-5	-7	-9	-11	-13	-15	-17	-19	-21	-22	-23	-25
	Correction in dB if acoustically "hard" surface																	
All Heights	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12

Effective total height above ground

No barrier — effective total height = s + r

With barrier
— effective total height = s + t + p + r



With barrier (depressed road)
— effective total height = s + t + p + r

With barrier (depressed site)
— effective total height = s + t + p + r

Effective total height = s + p + r

Effective total height = s + t + r

Table 3.6 - Effective barrier length ratio (w) for asymmetric barriers

Ratio v/g	Ratio u/g: over 9.5	8.6 to 9.5	7.6 to 8.5	6.6 to 7.5	5.6 to 6.5	4.6 to 5.5	3.6 to 4.5	2.8 to 3.5	2.3 to 2.7	1.8 to 2.2	1.3 to 1.7	0.9 to 1.2	0.6 to 0.8	0.36 to 0.50	0.15 to 0.35	less than 0.15
over 9.5	10.0	9.0	9.0	8.0	7.0	6.0	5.0	4.0	4.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
8.6 - 9.5	9.0	9.0	8.0	7.0	7.0	6.0	5.0	4.0	4.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
7.6 - 8.5	9.0	8.0	8.0	7.0	7.0	6.0	5.0	4.0	4.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
6.6 - 7.5	8.0	7.0	7.0	7.0	6.0	6.0	5.0	4.0	3.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
5.6 - 6.5	7.0	7.0	7.0	6.0	6.0	5.0	5.0	4.0	3.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
4.6 - 5.5	6.0	6.0	6.0	6.0	5.0	5.0	4.0	4.0	3.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
3.6 - 4.5	5.0	5.0	5.0	5.0	5.0	4.0	4.0	3.0	3.0	2.5	2.0	1.5	1.0	1.0	0.7	0.7
2.8 - 3.5	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	2.5	2.5	2.0	1.5	1.0	1.0	0.7	0.7
2.3 - 2.7	4.0	4.0	4.0	4.0	4.0	3.0	3.0	2.5	2.5	2.0	2.0	1.5	1.0	1.0	0.7	0.7
1.8 - 2.2	3.0	3.0	3.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	1.5	1.5	1.0	1.0	0.7	0.7
1.3 - 1.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	0.7	0.7
0.9 - 1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.0	1.0	0.7	0.7	0.7	0.5
0.6 - 0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.5	0.5	0.3
0.36- 0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.5	0.5	0.3	0.0
0.15- 0.35	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.3	0.3	0.0
less than 0.15	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.3	0.0	0.0	0.0

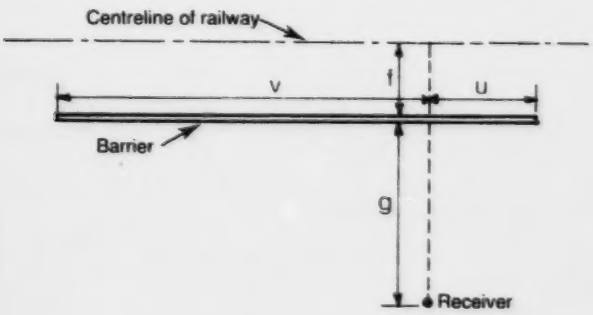


Fig. 3d — Plan view of roadside barrier

NOTE : 1) Where both u/g and v/g are greater than 15, the barrier shall be treated as a barrier of infinite length.

Table 3.7 - Barrier attenuation (in dB) for various values of the effective barrier length ratio (w)

Path Length Difference (in metres)		Effective Barrier Length Ratio (w) 0.3	0.5	0.7	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	Infinite Length
		Barrier Attenuation (in dB)															
barrier does not interrupt line of sight	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.05	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	0.04	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	0.03	1	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
	0.02	1	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4
	0.00	1	2	2	3	4	5	5	5	5	5	5	5	5	5	5	5
barrier does interrupt line of sight	0.03	1	2	3	4	5	6	6	6	6	6	6	6	6	6	6	6
	0.07	1	2	3	4	5	6	6	6	7	7	7	7	7	7	7	7
	0.13	1	2	3	4	6	7	7	7	8	8	8	8	8	8	8	8
	0.20	1	2	3	4	6	7	7	8	9	9	9	9	9	9	9	9
	0.30	1	2	3	4	6	7	8	9	9	10	10	10	10	10	10	10
	0.41	1	2	3	4	6	7	8	9	10	10	11	11	11	11	11	11
	0.55	1	2	3	4	6	8	9	10	11	11	12	12	12	12	12	12
	0.79	1	2	3	4	6	8	9	10	11	11	12	12	12	12	12	13
	1.0	1	2	3	4	6	8	9	10	11	12	12	13	13	13	13	14
	1.4	1	2	3	4	6	8	9	10	11	12	12	13	14	14	14	15
	1.8	1	2	3	4	6	8	9	10	12	13	13	14	14	14	15	16
	2.5	1	2	3	4	6	8	9	10	12	13	14	15	15	15	16	17
	3.3	1	2	3	4	6	8	9	11	12	13	15	15	16	16	17	18
	4.5	1	2	3	4	6	8	9	11	12	14	15	16	17	17	18	19
	6.0	2	3	3	5	7	8	10	11	13	15	16	17	18	18	19	20

Source : National Research Council of Canada, Division of Building Research, June 1980.

NOTE : 1) Where the calculated path length difference is not found in the table, the nearest value in the table should be used.

PART 4 — RAIL TRAFFIC NOISE

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Section A — Rail Traffic Noise

Introduction

A comparison might be attempted of the effects of highway noise and railway noise, because both have equally high noise levels. However, the similarity ends there since railway noise consists generally of a series of separate events, all similar in character, whereas highway noise is more continuous, though with random fluctuations.

The noise generated by railway trains is associated with three sources -- the engine, the whistle and the interaction of the wheels and the rails. Because the propagation of noise from these sources is quite different, the noise which each generates at the site must be evaluated separately. The contributions from the three components of railway noise are combined by the procedure given in Part 5.

Cautionary Note

Caution should be exercised when building within 100 m of a railway line. At these distances there is a possibility of high vibration levels within the building due to both ground vibration and airborne noise. In situations such as this, it is recommended that heavyweight construction be used and that a qualified person be consulted about other forms of vibration control which may be necessary.

Main Sources of Noise

There are three major sources of noise from railway rolling stock: the locomotive-engine noise, the movement of the wheels over the tracks, and the audible warning whistle device. Again there are a number of factors directly affecting the amount of noise an individual hears:

- Train Composition - the number of locomotives and railway cars in a train affect both the engine and the wheel-rail noise.
- Track Condition - long, smooth, welded rails are quieter than short rails with open expansion joints. However, guidelines assume that the latter are used.
- Train Speed - as the speed increases, so does the engine and wheel-rail noise. Changes in speed alter the duration of whistle noise.

Section B — Prediction of Outdoor Noise from Rail Traffic

This section outlines a procedure for taking account of the variables discussed in Part 4, Section A.

Step 1 - Traffic Characteristics

To determine the noise level generated by the locomotive engine and train wheels, the following information about a site is required and is available from a railway operations officer.

1. Nominal train speed in kilometers per hour.
2. Total number of locomotives in 24 hours.

   NOTE : A self-powered rail car shall be counted as one locomotive if diesel-powered, or as two railway cars if electrically powered.
3. Total number of railway cars in 24 hours.
4. Total number of whistle points (if any) within 750 m of the site.

Step 2 - Calculation of Engine Noise

To calculate the noise emitted by a railway locomotive requires the average train speed and the average number of railway cars pulled by each locomotive. The latter is obtained by dividing the number of cars by the number of locomotives for the 24-hour period.

The noise level at a distance of 30 m from the railway centreline for a train speed of 80 km/h is then obtained from Table 4.1.

Table 4.2 gives the corrections to be added to this value to obtain the noise level for other train speeds.

For horizontal distances other than 30 m, the procedures of Step 4 are used, for propagation over "hard" or "soft" ground as the case may be. For locomotive noise, the source height is taken to be 4 m above the track.

The noise from railway locomotives may be reduced by the presence of an obstruction that interrupts the line of sight between the engine and the observation point. Calculate the barrier attenuation, following the procedure of Step 5, using a source height of 4 m above the track.

Step 3 - Calculation of Wheel-Rail Noise

Obtain the wheel-rail noise level at a point 30 m from the track centreline from Table 4.3, using the train speed and the number of cars obtained in Step 1.

For horizontal distances other than 30 m, the procedures of Step 4 are used, for propagation over "hard" or "soft" ground as the case may be. For wheel-rail noise, the source height is taken to be 0.5 m above the track.

If the line of sight between the source and the observation point is interrupted, calculate the barrier attenuation, following the procedure of Step 5 with the source height 0.5 m above the track.

Step 4 - Correction for Distance

The procedure up to Step 4 gives the noise levels for a receiving point 30 m from the centreline of the track, when the ground surface is hard. If the receiver position or the ground surface are different from this, the noise level may be higher or lower. In general, the noise level diminishes as the distance between source and receiver is increased.

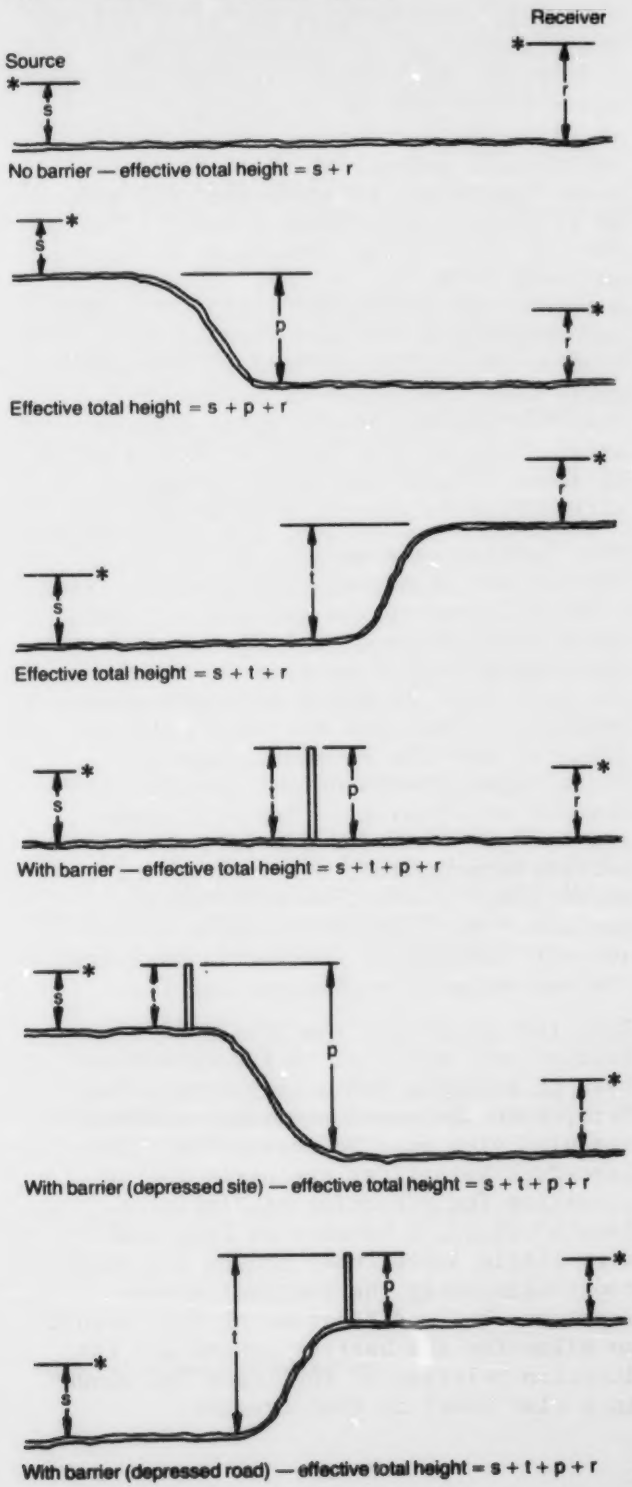
An acoustically "hard" surface is one that reflects sound well. This would include such surfaces as concrete, asphalt, clay or compacted gravel. If more than half the ground surface between the source and receiver is "hard", the distance correction should be calculated, using the section of Table 4.4 for "hard" ground.

Because the distance from the source to a receiving point above or below source height is greater than the horizontal

distance, lower outdoor noise levels would be expected at the upper storeys of a multi-floor building than at road level. However this reduction in outdoor noise levels is offset by the dependence of the building's noise insulation on the angle from which sound arrives. For this reason, the distance correction is based only on the horizontal distance if the ground surface is "hard".

If more than half the surface between the source and receiver is "soft" (e.g., planted with grass, shrubbery or other dense vegetation) an extra reduction in the noise will occur if the path of the sound from source to receiver is near the ground. The height of the source and receiver above the ground and the height of any intervening barrier affect the noise reduction associated with a soft surface. An "effective total height" must be calculated from the heights mentioned above, using the expression given in the appropriate diagrams in Fig. 4a. Then, using this effective total height and the horizontal distance, obtain the distance correction from the section of Table 4.4 for "soft" ground surface.

Fig. 4a Effective total height above ground


Receiver
Source
s
r
No barrier — effective total height = s + r
p
Effective total height = s + p + r
t
Effective total height = s + t + r
With barrier — effective total height = s + t + p + r
With barrier (depressed site) — effective total height = s + t + p + r
With barrier (depressed road) — effective total height = s + t + p + r

Step 5 - Correction for Barriers

The noise from railways may be reduced by the presence of any obstruction that interrupts the line of sight between the noise source and the receiving point, except trees and shrubs, which provide very little shielding. Note that the noise source may be above the rail bed, as is indicated in Steps 2 and 3. The barrier might be an embankment or cutting, an earth berm, one or more buildings, or a specially constructed wall. If a wall is constructed for this purpose, it must have an impervious surface with a negligible number of holes or cracks (less than 0.2 percent of the total surface area). The barrier material should weigh at least 5 kg/m^2 (10 kg/m^2 if barrier attenuation is greater than 10 dB).

The "barrier attenuation" is the reduction in the noise level at a receiving point relative to the noise level that would exist there if the ground surface were "hard" and if nothing interrupted the path from the noise source to the receiver. Note that the correction for distance when the ground surface is "soft" also depends on the presence or absence of a barrier. Typically, the addition of a barrier provides some barrier attenuation, but reduces the noise level provided by soft ground surface. The trade-off between these two effects must be weighed in assessing the net value of a proposed barrier.

Both the height and the length of a barrier are important to its effectiveness in reducing the noise level. Therefore, both the vertical cross-section and the plan view must be considered. The procedure here first evaluates the attenuation for a barrier of "infinite length" (i.e., a barrier so long that very little noise comes around the ends) considering only the vertical cross-section. The modification of this result to allow for the barrier length and its location relative to the track (as shown in a plan view) is then treated.

Attenuation for a Barrier of Infinite Length

The fundamental barrier geometry is illustrated by Fig. 4b, which is a vertical section along the line from the noise source to the receiving point. The distance "s" is the equivalent height of the noise source above the road surface, which is determined in Steps 2 and 3.

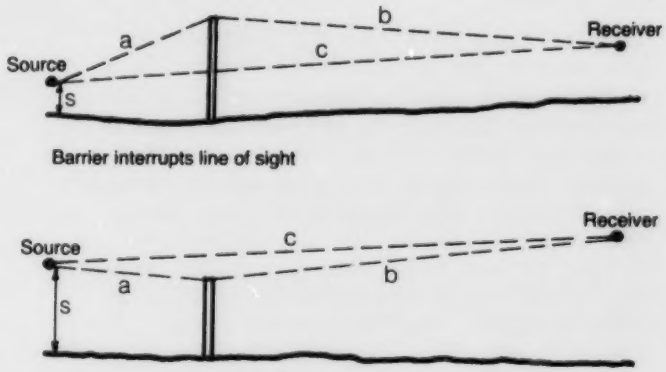


Fig. 4b — Basic barrier model (vertical section)

For a barrier of infinite length, the attenuation depends on the difference between the straight line distance (c) from source to receiver in Fig. 4b and the combined distance (a + b) from the source to the top of the barrier and then to the receiver. This is called the "path length difference".

Calculating the path length difference is straightforward. The necessary horizontal and vertical distances are indicated in Fig. 4c for the two important cases where the barrier interrupts the line of sight and where the barrier nearly interrupts the line of sight.

The distances "a", "b", and "c" may be calculated using the expressions:

$$a = \sqrt{x^2 + f^2}$$

$$b = \sqrt{y^2 + g^2}$$

$$c = \sqrt{z^2 + (f + g)^2}$$

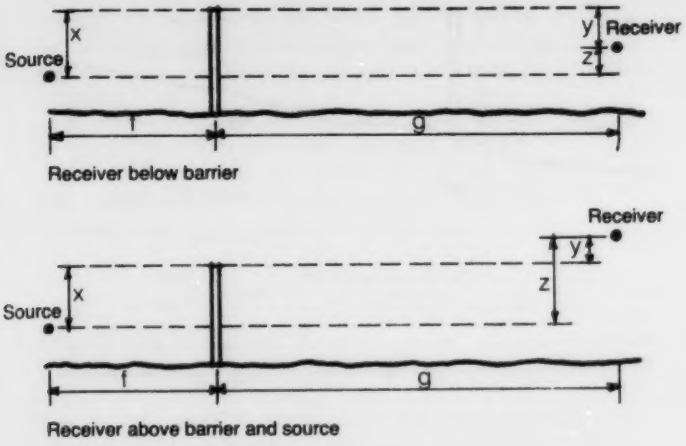


Fig. 4c — Necessary dimensions for calculation of barrier attenuation

Note : "x" is the difference in elevation between the source and the top of the barrier. "y" is the difference in elevation between the receiver and the top of the barrier. "z" is the difference in elevation between the source and the receiver.

In calculating the value of c, the horizontal distance used should be the exact sum of the other two horizontal distances; the vertical distances should be the exact sum or difference of x and y, as indicated in Fig. 4c. All the square roots should be calculated to an accuracy of 0.01 m. Note that this does not mean that this accuracy is required in the original distances such as f and g.

(Note : inexpensive electronic calculators which can compute squares and square roots are readily available.)

The path length difference = a + b - c. If the barrier does not interrupt the line of sight from the source to the receiver, and the path length difference is 0.06 m or greater, the barrier attenuation is zero, and no further calculations are required. In other cases, the path length difference may be used with Table 4.6 to obtain the attenuation for a barrier of infinite length.

The calculations using the path length difference are appropriate for continuous barriers such as berms, specially constructed fences or row housing. However, some attenuation may also be provided by rows of detached buildings that are sufficiently closely spaced (average space between buildings less than 50 percent of average building length). For the first row of buildings obstructing the line of sight between the source and the receiving point, allow a barrier attenuation of 4 dB. Further attenuations of 2 dB each may be allowed for the second, third and fourth rows respectively. If both a continuous barrier and one or more rows of buildings are present, an attenuation of 2 dB per row may be allowed for each of the first three rows of buildings interrupting the line of sight from the top of the barrier to the receiving point. The combined attenuation for the continuous barrier and the row(s) of housing may not exceed 20 dB. Note that these attenuations must be corrected for the actual length of the rows of buildings, following the procedure outlined in the next section, "Correction for Actual Barrier Length".

Correction for Actual Barrier Length

A plan view of a barrier is shown in Fig. 4d. A line from the receiving point to the centreline of the railway divides the barrier into two segments, one of length v and the other of length u.

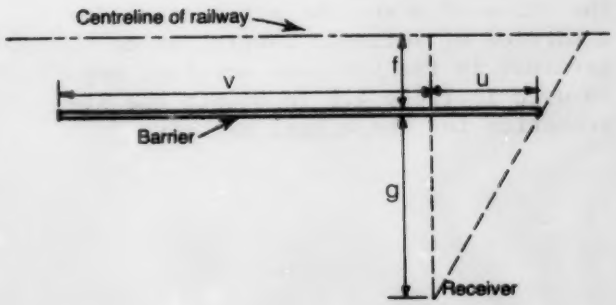


Fig. 4d — Plan view of railside barrier

If the barrier is not parallel to the rail track, the procedure is to consider an equivalent barrier parallel to the track, as shown in Fig. 4e. The equivalent barrier is represented by the broken line parallel to the railway and screening the same portion of the railway track.

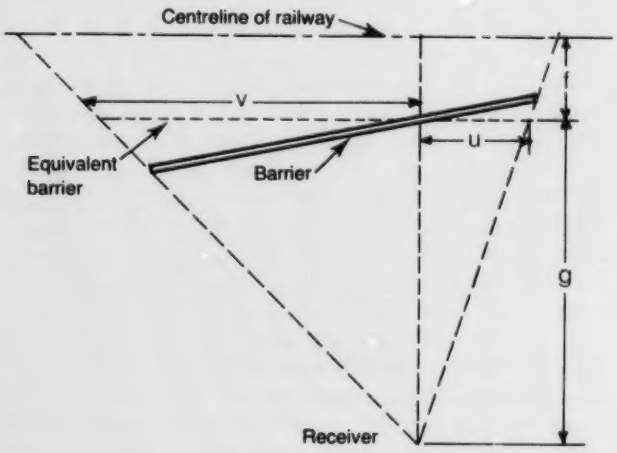


Fig. 4e — Plan view of an equivalent parallel barrier

The values of these ratios u/g and v/g are used in conjunction with Table 4.5 to determine the effective barrier length ratio (w). If the value of w is less than 10, a significant amount of noise may reach the receiving point via paths around the ends of the barrier. The value of w and the attenuation for a barrier of infinite length, as determined in the previous section, may be used in Table 4.6 to obtain the attenuation for the actual barrier.

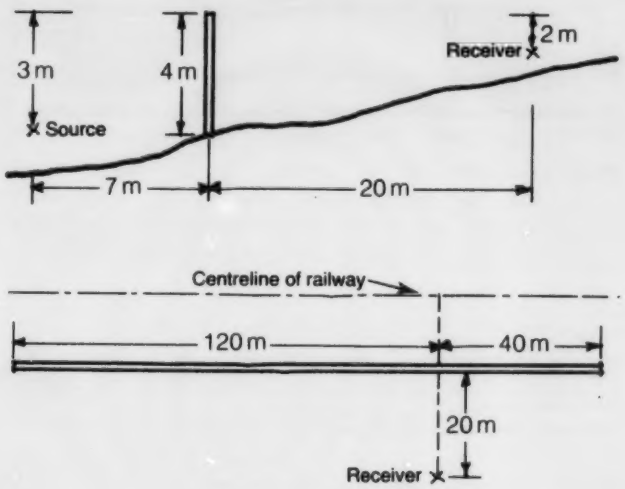


Fig. 4f — Numerical example of work procedure

Numerical Example of Work Procedure

In the example in Fig. 4f, the source is 3 m below and 7 m horizontally from the top of the barrier. The direct distance from source to barrier top is
$a = \sqrt{(3 \times 3) + (7 \times 7)} = 7.62$ m.

The vertical and horizontal distances from the top of the barrier to the receiver are 2 m and 20 m respectively; the direct distance is
$b = \sqrt{(2 \times 2) + (20 \times 20)} = 20.10$ m.

The receiving point is 1 m above the source and 27 m away horizontally; the direct source receiver distance is therefore
$c = \sqrt{(1 \times 1) + (27 \times 27)} = 27.02$ m.

The barrier interrupts the line of sight from the source to receiver and the path length difference is
$7.62 + 20.10 - 27.02 = 0.70$ m. For a barrier of infinite length, the barrier attenuation, as given in Table 4.6, would be 13 dB.

From Fig. 4f it is seen that u = 40 m, v = 120 m and g = 20 m. Therefore:

$u/g = 40/20 = 2$
$v/g = 120/20 = 6$

These values can be used with Table 4.5 to obtain the effective barrier length ratio (w), which is found to be 3.

The path length difference (0.70 m) and the effective barrier length ratio (w = 3) can now be used in Table 4.6 to give the barrier attenuation for the actual barrier, which is 10 dB.

Further numerical examples illustrating other common barrier configurations are given in Appendix B.

Step 6 - Calculation of Whistle Noise

Where an audible warning is required, the sounding of the whistle must, by law, start 400 m before and continue up to a point where the warning is necessary. Train speed does not alter the loudness of the whistle noise, but does change the duration of the noise and therefore the noise level.

The noise level at a site depends on the distance from the site to the centreline of the track, and the distance from that point on the railway to the point where the audible warning is required. Table 4.7 gives the whistle noise level for a single train passing by at 80 km/h (assuming that half the trains approach the warning point from one direction and half from the other).

If the terrain between the railway and the receiving point is reasonably flat and has a soft surface, a "ground attenuation" correction may be applied. For whistle noise, the source is located 4 m above the track, and the distance from the receiving point to the nearest point at which the whistle is sounded is taken as the horizontal distance. Because of the special geometry of the whistle zone, the corrections for distance and for ground attenuation are best treated individually. Distance corrections are incorporated in Table 4.7; the additional ground attenuation correction is given in Table 4.8. Finally, to account for the actual number of trains and their average speed, add the correction in Table 4.9.

Whistle noise may be reduced by the presence of a barrier that interrupts the line of sight between the source and the receiving point. The source of whistle noise is located 4 m above the track. The procedure outlined in Step 5 may be used to calculate the barrier attenuation, except that Fig. 4d is replaced by Fig. 4g or 4h. In this case, the line from the receiver to the nearest point in the whistle zone is divided into two parts, f and g, by the barrier. The line also divides the barrier into two segments, one of length v and one of length u. If the barrier is not parallel to the railway track, the calculation is done for an equivalent barrier parallel to the track which intersects the line at the same point and screens the same portion of the track. This is illustrated in Fig. 4e. The length g, u and v can then be used as described in Step 5 of "Correction for Actual Barrier Length."

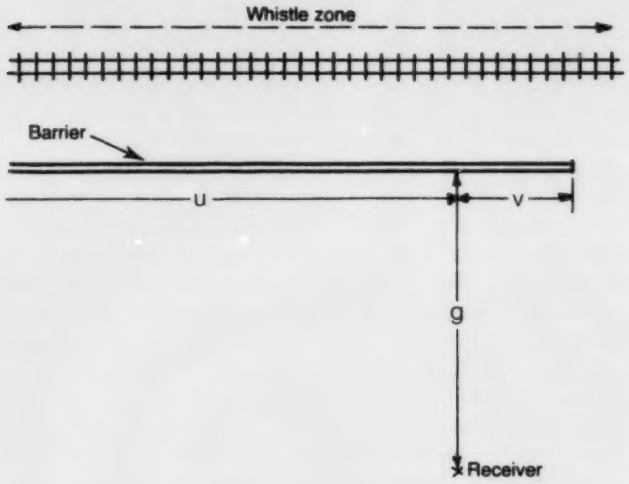


Fig. 4g — Plan view of barrier for whistle noise where receiving point is within whistle zone

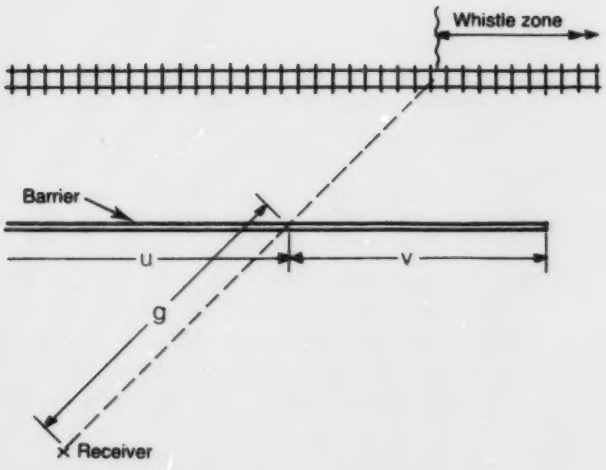


Fig. 4h — Plan view of barrier for whistle noise where receiving point is offset from whistle zone

Table 4.1 - Engine noise (in dB) at 30 m from track for train speed of 80 km/h

Total number of locomotives per day	Average number of cars/locomotives							
	1-4	5-11	12-18	19-25	26-32	33-39	40-46	47-53
4 or fewer	50	51	52	53	54	55	56	57
5	51	52	53	54	55	56	57	58
6	52	53	54	55	56	57	58	59
7 - 8	53	54	55	56	57	58	59	60
9 - 10	54	55	56	57	58	59	60	61
11 - 13	55	56	57	58	59	60	61	62
14 - 17	56	57	58	59	60	61	62	63
18 - 22	57	58	59	60	61	62	63	64
23 - 28	58	59	60	61	62	63	64	65
29 - 35	59	60	61	62	63	64	65	66
36 - 45	60	61	62	63	64	65	66	67
46 - 56	61	62	63	64	65	66	67	68
57 - 71	62	63	64	65	66	67	68	69
72 - 90	63	64	65	66	67	68	69	70
91 - 110	64	65	66	67	68	69	70	71
111 - 142	65	66	67	68	69	70	71	72
143 - 180	66	67	68	69	70	71	72	73
181 - 225	67	68	69	70	71	72	73	74

Table 4.2 - Correction (in dB) to engine noise for actual train speed

Actual Train Speed km/h	Up to 34	35-43	44-51	52-61	62-74	75-86	87-105	over 105
Correction (dB)	-5	-4	-3	-2	-1	0	-1	-2

Table 4.3 - Wheel-Rail noise (in dB) at 30 m from track

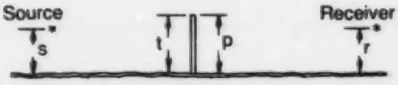
Total number of railway cars per day	Train Speed (km/h)												
	up to 27	28 to 29	30 to 34	35 to 40	41 to 47	48 to 53	54 to 61	62 to 72	73 to 84	85 to 97	98 to 111	112 to 129	over 129
up to 70	42	43	44	45	46	47	48	49	50	51	52	53	54
71 - 90	43	44	45	46	47	48	49	50	51	52	53	54	55
91 - 110	44	45	46	47	48	49	50	51	52	53	54	55	56
111 - 140	45	46	47	48	49	50	51	52	53	54	55	56	57
141 - 180	46	47	48	49	50	51	52	53	54	55	56	57	58
181 - 220	47	48	49	50	51	52	53	54	55	56	57	58	59
221 - 280	48	49	50	51	52	53	54	55	56	57	58	59	60
281 - 350	49	50	51	52	53	54	55	56	57	58	59	60	61
351 - 440	50	51	52	53	54	55	56	57	58	59	60	61	62
441 - 560	51	52	53	54	55	56	57	58	59	60	61	62	63
561 - 700	52	53	54	55	56	57	58	59	60	61	62	63	64
701 - 890	53	54	55	56	57	58	59	60	61	62	63	64	65
891 - 1120	54	55	56	57	58	59	60	61	62	63	64	65	66
1121 - 1400	55	56	57	58	59	60	61	62	63	64	65	66	67
1401 - 1770	56	57	58	59	60	61	62	63	64	65	66	67	68
1771 - 2230	57	58	59	60	61	62	63	64	65	66	67	68	69
2231 - 2800	58	59	60	61	62	63	64	65	66	67	68	69	70

Table 4.4 - Correction (in dB) for distance from source to receiver and for total effective height above ground

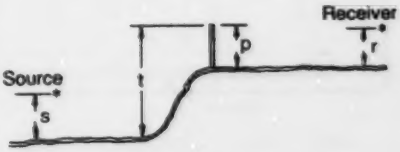
Effective Total Height Above Ground (metres)	HORIZONTAL DISTANCE IN METRES FROM SOURCE TO RECEIVING POINT																	
	up to 11	11 to 14	15 to 18	19 to 22	23 to 27	28 to 35	36 to 45	46 to 57	58 to 72	73 to 90	91 to 112	113 to 142	143 to 180	181 to 225	226 to 275	276 to 350	351 to 450	451 or over
	Correction in dB if acoustically "soft" surface																	
58.0 or over	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-11	-13	-15
45.1 to 57.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8	-10	-12	-14	-16
36.1 to 45.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-9	-11	-13	-15	-17
28.1 to 36.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-8	-10	-12	-14	-16	-18
22.1 to 28.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-7	-9	-11	-13	-15	-17	-19
18.1 to 22.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-6	-8	-10	-12	-14	-16	-18	-20
14.1 to 18.0	+5	+4	+3	+2	+1	0	-1	-2	-3	-5	-7	-9	-11	-13	-15	-17	-18	-20
11.1 to 14.0	+5	+4	+3	+2	+1	0	-1	-2	-4	-6	-8	-10	-12	-14	-16	-17	-19	-21
9.1 to 11.0	+5	+4	+3	+2	+1	0	-1	-3	-5	-7	-9	-11	-13	-15	-17	-18	-20	-21
7.1 to 9.0	+5	+4	+3	+2	+1	0	-2	-4	-6	-8	-10	-12	-14	-16	-17	-19	-20	-22
5.6 to 7.0	+5	+4	+3	+2	+1	-1	-3	-5	-7	-9	-11	-13	-14	-16	-18	-19	-20	-22
4.1 to 5.5	+5	+4	+3	+2	0	-2	-4	-6	-8	-10	-12	-14	-15	-17	-18	-20	-21	-23
2.6 to 4.0	+5	+4	+3	+1	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-19	-21	-22	-24
up to 2.5	+5	+4	+3	+1	-1	-3	-5	-7	-9	-11	-13	-15	-17	-19	-21	-22	-23	-25
	Correction in dB if acoustically "hard" surface																	
All Heights	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12

Effective total height above ground

No barrier — effective total height = s + r



With barrier
— effective total height = s + t + p + r



With barrier (depressed road)
— effective total height = s + t + p + r

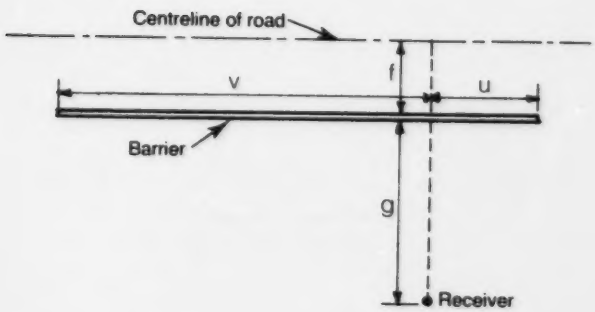
With barrier (depressed site)
— effective total height = s + t + p + r

Effective total height = s + p + r

Effective total height = s + t + r

Table 4.5 - Effective barrier length ratio (w) for asymmetric barriers

Ratio v/g	Ratio u/g														
	over 9.5	8.6 to 9.5	7.6 to 8.5	6.6 to 7.5	5.6 to 6.5	4.6 to 5.5	3.6 to 4.5	2.8 to 3.5	2.3 to 2.7	1.8 to 2.2	1.3 to 1.7	0.9 to 1.2	0.6 to 0.8	0.36 to 0.5	0.15 to 0.35	less than 0.15
over 10.0	10.0	9.0	9.0	8.0	7.0	6.0	5.0	4.0	4.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
8.6 - 9.5	9.0	9.0	8.0	7.0	7.0	6.0	5.0	4.0	4.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
7.6 - 8.5	9.0	8.0	8.0	7.0	7.0	6.0	5.0	4.0	4.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
6.6 - 7.5	8.0	7.0	7.0	7.0	6.0	6.0	5.0	4.0	3.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
5.6 - 6.5	7.0	7.0	7.0	6.0	6.0	5.0	5.0	4.0	3.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
4.6 - 5.5	6.0	6.0	6.0	6.0	5.0	5.0	4.0	4.0	3.0	3.0	2.0	1.5	1.0	1.0	0.7	0.7
3.6 - 4.5	5.0	5.0	5.0	5.0	5.0	4.0	4.0	3.0	3.0	2.5	2.0	1.5	1.0	1.0	0.7	0.7
2.8 - 3.5	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	2.5	2.5	2.0	1.5	1.0	1.0	0.7	0.7
2.3 - 2.7	4.0	4.0	4.0	4.0	4.0	3.0	3.0	2.5	2.5	2.0	2.0	1.5	1.0	1.0	0.7	0.7
1.8 - 2.2	3.0	3.0	3.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	1.5	1.5	1.0	1.0	0.7	0.7
1.3 - 1.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	0.7	0.7
0.9 - 1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.0	1.0	0.7	0.7	0.7	0.5
0.6 - 0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.5	0.5	0.3
0.36- 0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.5	0.5	0.3	0.0
0.15- 0.35	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.3	0.3	0.0
less than 0.15	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.3	0.0	0.0	0.0



NOTE : 1) Where both u/g and v/g are greater than 15, the barrier shall be treated as a barrier of infinite length.

Table 4.6 - Barrier attenuation (in dB) for various values of the effective barrier length ratio (w)

Path Length Difference (in metres)		Effective Barrier Length Ratio (w) 0.3	0.5	0.7	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	Infinite Length
		Barrier Attenuation (in dB)															
barrier	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
does not	0.05	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
interrupt	0.04	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
line of	0.03	1	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
sight	0.02	1	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4
	0.00	1	2	2	3	4	5	5	5	5	5	5	5	5	5	5	5
	0.03	1	2	3	4	5	6	6	6	6	6	6	6	6	6	6	6
barrier	0.07	1	2	3	4	5	6	6	6	7	7	7	7	7	7	7	7
does	0.13	1	2	3	4	6	7	7	7	8	8	8	8	8	8	8	8
interrupt	0.20	1	2	3	4	6	7	7	8	9	9	9	9	9	9	9	9
line of	0.30	1	2	3	4	6	7	8	9	9	10	10	10	10	10	10	10
sight	0.41	1	2	3	4	6	7	8	9	10	10	11	11	11	11	11	11
	0.55	1	2	3	4	6	8	9	10	11	11	12	12	12	12	12	12
	0.79	1	2	3	4	6	8	9	10	11	11	12	12	12	12	12	13
	1.0	1	2	3	4	6	8	9	10	11	12	12	13	13	13	13	14
	1.4	1	2	3	4	6	8	9	10	11	12	12	13	14	14	14	15
	1.8	1	2	3	4	6	8	9	10	12	13	13	14	14	14	15	16
	2.5	1	2	3	4	6	8	9	10	12	13	14	15	15	15	16	17
	3.3	1	2	3	4	6	8	9	11	12	13	15	15	16	16	17	18
	4.5	1	2	3	4	6	8	9	11	12	14	15	16	17	17	18	19
	6.0	2	3	4	5	7	8	10	11	13	15	16	17	18	18	19	20

Source : National Research Council of Canada, Division of Building Research, June 1980.

NOTE : 1) Where the calculated path length difference is not found in the table, the nearest value in the table should be used.

Table 4.7 - Whistle noise (in dB) for a single train travelling at 80 km/h if ground surface is "hard"

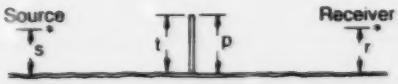
Shortest Distance To Track in Metres	Distance along track from warning point in metres														
	up to 320	321 to 365	366 to 395	396 to 417	418 to 432	433 to 447	448 to 462	463 to 477	478 to 502	503 to 535	536 to 565	566 to 602	603 to 655	656 to 715	716 or over
up to 13	59	58	57	53	50	48	47	46	45	44	42	41	40	39	38
14 - 16	58	57	56	53	50	48	47	46	45	44	42	41	40	39	38
17 - 21	57	56	55	52	50	48	47	46	45	43	42	41	40	39	38
22 - 27	56	55	54	52	50	48	47	46	45	43	42	41	40	39	38
28 - 33	55	54	53	51	49	48	47	46	45	43	42	41	40	39	38
34 - 40	54	53	52	50	49	48	46	46	45	43	42	41	40	39	38
41 - 47	53	52	51	49	48	47	46	46	45	43	42	41	40	39	38
48 - 55	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38
56 - 65	51	50	49	48	47	47	46	45	44	43	42	41	40	39	38
66 - 80	50	49	48	48	47	46	45	44	44	43	42	41	40	39	38
81 - 97	49	48	47	47	46	45	44	44	43	42	41	41	40	39	38
98 - 115	48	47	46	46	46	45	44	44	43	42	41	41	40	39	38
116 - 135	47	46	45	45	45	44	44	44	43	42	41	40	39	38	38
136 - 165	46	45	44	44	44	43	43	43	42	41	41	40	39	38	38
166 - 195	45	44	43	43	43	43	42	42	42	41	41	40	39	38	37
196 - 225	44	43	43	43	42	42	42	42	42	41	40	40	38	38	37
226 - 260	43	42	42	42	42	41	41	41	41	40	40	39	38	38	37
261 - 295	42	42	41	41	41	41	41	41	41	40	39	38	38	37	36
296 - 340	41	41	41	41	40	40	40	40	40	39	39	38	37	37	36
341 - 400	40	40	40	40	39	39	39	39	39	38	38	37	37	36	36
401 - 460	39	39	39	39	39	38	38	38	38	37	37	37	36	36	35
461 or over	39	38	38	38	38	38	38	37	37	37	37	37	36	36	35

Table 4.8 - Correction (in dB) to be subtracted from whistle noise level if ground surface is "soft"

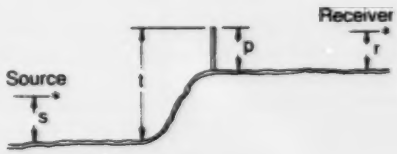
Effective Total Height Above Ground in Metres	Shortest horizontal distance to track in metres																
	up to 14	15 to 18	19 to 22	23 to 27	28 to 35	36 to 45	46 to 57	58 to 72	73 to 90	91 to 112	113 to 142	143 to 180	181 to 225	226 to 275	276 to 350	351 to 450	451 or over
58.0 or over	0													0	1	2	3
45.1 to 57.0	0												0	1	2	3	4
36.1 to 45.0	0											0	1	2	3	4	5
28.1 to 36.0	0										0	1	2	3	4	5	6
22.1 to 28.0	0									0	1	2	3	4	5	6	7
18.1 to 22.0	0								0	1	2	3	4	5	6	7	8
14.1 to 18.0	0							0	1	2	3	4	5	6	7	7	8
11.1 to 14.0	0						0	1	2	3	4	5	6	7	7	8	9
9.1 to 11.0	0					0	1	2	3	4	5	6	7	8	8	9	9
7.1 to 9.0	0				0	1	2	3	4	5	6	7	8	8	9	9	10
5.6 to 7.0	0			0	1	2	3	4	5	6	7	7	8	9	9	10	10
4.1 to 5.5	0		0	1	2	3	4	5	6	7	8	8	9	9	10	10	11

Effective total height above ground

No barrier — effective total height = s + r



With barrier
— effective total height = s + t + p + r



With barrier (depressed road)
— effective total height = s + t + p + r

With barrier (depressed site)

Effective total height = s + p + r

Effective total height = s + t + r

Table 4.9 - Correction (in dB) to whistle noise for train speed and number of trains per day

Number of trains per day	Actual train speed (km/h)							
	up to 27	28 to 35	36 to 45	46 to 56	57 to 72	73 to 90	91 to 114	above 114
1	5	4	3	2	1	0	-1	-2
2	8	7	6	5	4	3	2	1
3	10	9	8	7	6	5	4	3
4	11	10	9	8	7	6	5	4
5	12	11	10	9	8	7	6	5
6	13	12	11	10	9	8	7	6
7-8	14	13	12	11	10	9	8	7
9-10	15	14	13	12	11	10	9	8
11-13	16	15	14	13	12	11	10	9
14-17	17	16	15	14	13	12	11	10
18-22	18	17	16	15	14	13	12	11
23-28	19	18	17	16	15	14	13	12
29-35	20	19	18	17	16	15	14	13
36-45	21	20	19	18	17	16	15	14
46-56	22	21	20	19	18	17	16	15
57-71	23	22	21	20	19	18	17	16
72-90	24	23	22	21	20	19	18	17
91-110	25	24	23	22	21	20	19	18
111-142	26	25	24	23	22	21	20	19
143-180	27	26	25	24	23	22	21	20
181-225	28	27	26	25	24	23	22	21

PART 5 — COMBINING NOISE LEVELS

Contents

Noise Levels From Single and Multiple Sources

Introduction
Noise Levels from a Single Source
Combination of Levels from Multiple Sources
Example of Combined Levels for Several Sources

Table

5.1 Corrections for combining noise levels, expressed in dB

Noise Levels From Single and Multiple Sources

Introduction

In Parts 3 and 4, methods were developed for predicting the noise level on a proposed building site made by traffic on a nearby road or railway. Two further points must be considered in determining the noise exposure of the building:

- Because the building itself shields some facades from an adjacent traffic route, each building wall should be considered separately to determine the incident noise level and hence the required sound insulation.

- Because, in many cases, more than one road or railway contributes to the noise level at a building wall, a procedure is required for combining the contributions from a number of sources.

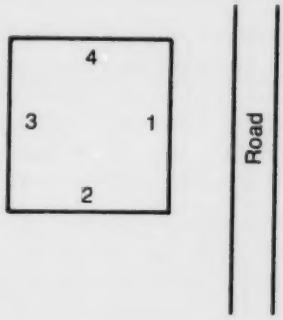
Noise Levels from a Single Source

The noise level for a building wall facing a traffic route may be calculated by following the steps outlined in Parts 3 or 4. The noise levels for the flanking walls perpendicular to the roadway (Walls 2 and 4 in the diagram below) are 3 dB lower because the building screens these walls from half the noise source. The building provides additional screening of 15 dB for the wall sheltered from the road or railway.

The same rules may be applied to a single row of buildings parallel to a traffic route. If additional buildings are present, from which noise may be reflected to the "sheltered" wall (Wall 3 in the diagram), only a 10 dB reduction relative to the noise level at Wall 1 should be allowed.

Example: If the calculation in Section 3 gave a value of 67 dB at Wall 1, for the building shown in the diagram below, the levels at the four walls would be:

67 dB at Wall 1
64 dB at Wall 2
64 dB at Wall 4
52 dB at Wall 3



NOTE : For larger buildings, such as row houses, it may be necessary to allow for the reduction of noise as distance from the road or railway increases. A sample calculation is given in Appendix E - Example E.4.

Combination of Levels
from Multiple Sources

When the noise reaching a building wall comes from a number of sources, first establish the noise level from each individual source and then combine the levels progressively, following the procedure given below. Because the noise levels are expressed in decibels, they cannot be added directly. To combine the levels for two sources, first determine the numerical difference between the levels, and then add to the higher level the appropriate correction from Table 5.1. The effect of a third source may be included by repeating the calculation to combine the third level with the result for the first two levels, and so on for additional sources.

Example : To determine the combined level for Level A - 59 dB, Level B - 65 dB and Level C - 69 dB.

The difference between Level A and Level B is 6 dB.

Correction from Table 5.1	1 dB
Higher of the two levels	65 dB
Combined Levels A and B	66 dB

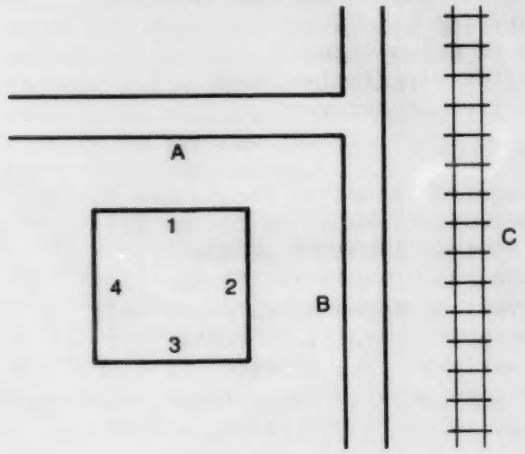
The difference between this combined level and Level C is 3 dB.

Correction from Table 5.1	2 dB
Higher of the two levels	69 dB
	71 dB

Thus the total combined level is 71 dB.

Example of Combined Levels for Several Sources

The building illustrated in the diagram on the right is influenced by noise from road A, road B and railway C. The noise level for each source would be determined as in Parts 3 and 4. Suppose that the noise level at Wall 1 from road A was calculated to be 65 dB; then at the mid-points of Walls 2 and 4, road A would contribute 62 dB and on Wall 3 the contribution would be 50 dB. Similarly, noises reaching Wall 2 from road B and railway C might be 66 dB and 70 dB respectively, and on Walls 1 and 3, 63 and 67 dB. The noise levels at the four walls are then determined by combining levels, using Table 5.1, with the results shown below.



Source	Wall 1	Wall 2	Wall 3	Wall 4
Road A	65 dB	62 dB	50 dB	62 dB
Road B	63 dB	66 dB	63 dB	51 dB
Railway C	67 dB	70 dB	67 dB	55 dB
Combined Level	70 dB	72 dB	69 dB	63 dB

Table 5.1 — Corrections for combining noise levels expressed in dB

If higher level exceeds lower level by	Add this correction to higher level
0 — 1 dB	3 dB
2 — 4 dB	2 dB
5 — 9 dB	1 dB
over 10 dB	0 dB

PART 6 — ADEQUATE SOUND INSULATION LEVELS

Contents

Section A - Adequate Sound Insulation
Introduction
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Alternative Procedures

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6.1 Required Acoustic Insulation Factor
6.2 Acoustic Insulation Factor for various types of window
6.3 Acoustic Insulation Factor for various types of exterior wall
6.4 Acoustic Insulation Factor for various types of exterior door
6.5 Component area percentages relative to total floor area of a room

Section A — Adequate Sound Insulation

Introduction

Where the noise levels are between 55 dB and 75 dB, it is recommended that adequate sound insulation be provided in new buildings. In addition, provision should be made for suitable outdoor amenity space with a noise level of 55 dB or less.

"Adequate sound insulation" is defined as the sound insulation provided in a dwelling unit in accordance with the recommendations established in this document.

Since conventional roof designs meeting Residential Standards provide sufficient noise reduction, roofs may be ignored in calculations for this guideline. The other components of the outer shell or "envelope" of a building include windows, doors and walls. To achieve the recommended noise reduction, each of these components must provide an appropriate degree of sound insulation.

The National Research Council has developed the following method which, when the noise level in dB has been determined, enables building components to be selected which will provide adequate sound insulation. These components are termed "appropriate building components".

The method for selecting appropriate building components is based on an Acoustic Insulation Factor (AIF), which takes into account the type of room under consideration, the number of components forming the room envelope, and the exterior noise level.

Because the building will at least partially screen several walls from any traffic route, a room might have two or more exterior walls with different noise levels. To take advantage of the lower noise levels on the sheltered walls, the design procedure considers each wall separately.

Method of Calculation

The appropriate building components for each exterior wall of any room in a dwelling may be determined by the following procedure:

Step 1:

Calculate the outdoor noise level for each wall, following the procedures detailed in Parts 3, 4 and 5.

Step 2:

Determine the room category:

- bedroom
- living room, dining room, recreation room
- kitchen, bathroom, hallways, utility rooms, and so on.

Step 3:

Determine the number of components which make up the exterior envelope of the room. Note that:

- where any wall of a building is shielded from noise, as explained in Part 5, and the noise level is 55 dB or less, the components of that wall are not included in the calculation.
- the actual number of doors or windows does not affect the determination of the AIF, since the AIF is related to the total area of that component for each wall.
- where a room has more than one exterior wall, the number of components for each exterior wall is determined and these numbers are added to obtain the number of components for the room.

Step 4:

For each exterior wall, obtain the required Acoustic Insulation Factor (using the total number of components for the room and the exterior noise level for that wall) from the appropriate section of Table 6.1.

Step 5:

Select the appropriate types of window, exterior wall and exterior door from Tables 6.2, 6.3 and 6.4 respectively, using the AIF obtained. Where the calculated AIF does not correspond directly to an AIF value given in the tables, the next highest value should be used. All the components so indicated are the minimum necessary to provide the degree of sound insulation recommended.

Use of the tables requires evaluating the total area of each component in each exterior wall as a percentage of floor area of the room. Having calculated the appropriate areas, the percentages are obtained from Table 6.5.

Tables 6.2, 6.3 and 6.4 have been compiled by the National Research Council from laboratory and field tests on various components. They may be revised from time to time as methods and standards of construction change and as the results of additional field tests become available and are evaluated.

Associated Ventilation Needs

The AIF values in the tables apply to closed, fully weatherstripped doors and windows. Because the noise insulation criteria cannot be met by conventional windows when they are open to provide ventilation, alternative means of ventilation are necessary if the noise level at that wall is above 55 dB (See Appendix C).

Alternative Procedures

Where a proponent wishes to give more detailed consideration to the problem of noise and the subject of sound insulation, he is advised to consult a person suitably qualified in acoustics.

NOTE : If, for non-acoustic reasons, a component is chosen whose AIF exceeds the requirements by 10 dB or more, it need not be counted as one of the room's components, and the required AIF, for the other components is reduced. For road or rail noise, only three types of components are considered to be relevant: exterior doors, windows and exterior walls. Roof-ceiling systems are ignored because most roof constructions used in Canada have AIF ratings that significantly exceed the requirements for sites where L_{eq} (outside) is less than 75 dB (A).

Table 6.1 - Required Acoustic Insulation Factor (AIF)

Noise level of building wall (dB)	Bedrooms								Living, dining, recreation								Kitchen, bathrooms							
	Number of components forming the room envelope																							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
55	22	25	27	28	29	30	31	31	17	20	22	23	24	25	26	26	12	15	17	18	19	20	21	21
56	23	26	28	29	30	31	32	32	18	21	23	24	25	26	27	27	13	16	18	19	20	21	22	22
57	24	27	29	30	31	32	33	33	19	22	24	25	26	27	28	28	14	17	19	20	21	22	23	23
58	25	28	30	31	32	33	34	34	20	23	25	26	27	28	29	29	15	18	20	21	22	23	24	24
59	26	29	31	32	33	34	35	35	21	24	26	27	28	29	30	30	16	19	21	22	23	24	25	25
60	27	30	32	33	34	35	36	36	22	25	27	28	29	30	31	31	17	20	22	23	24	25	26	26
61	28	31	33	34	35	36	37	37	23	26	28	29	30	31	32	32	18	21	23	24	25	26	27	27
62	29	32	34	35	36	37	38	38	24	27	29	30	31	32	33	33	19	22	24	25	26	27	28	28
63	30	33	35	36	37	38	39	39	25	28	30	31	32	33	34	34	20	23	25	26	27	28	29	29
64	31	34	36	37	38	39	40	40	26	29	31	32	33	34	35	35	21	24	26	27	28	29	30	30
65	32	35	37	38	39	40	41	41	27	30	32	33	34	35	36	36	22	25	27	28	29	30	31	31
66	33	36	38	39	40	41	42	42	28	31	33	34	35	36	37	37	23	26	28	29	30	31	32	32
67	34	37	39	40	41	42	43	43	29	32	34	35	36	37	38	38	24	27	29	30	31	32	33	33
68	35	38	40	41	42	43	44	44	30	33	35	36	37	38	39	39	25	28	30	31	32	33	34	34
69	36	39	41	42	43	44	45	45	31	34	36	37	38	39	40	40	26	29	31	32	33	34	35	35
70	37	40	42	43	44	45	46	46	32	35	37	38	39	40	41	41	27	30	32	33	34	35	36	36
71	38	41	43	44	45	46	47	47	33	36	38	39	40	41	42	42	28	31	33	34	35	36	37	37
72	39	42	44	45	46	47	48	48	34	37	39	40	41	42	43	43	29	32	34	35	36	37	38	38
73	40	43	45	46	47	48	49	49	35	38	40	41	42	43	44	44	30	33	35	36	37	38	39	39
74	41	44	46	47	48	49	50	50	36	39	41	42	43	44	45	45	31	34	36	37	38	39	40	40
75	42	45	47	48	49	50	51	51	37	40	42	43	44	45	46	46	32	35	37	38	39	40	41	41

Table 6.2 - Acoustic Insulation Factor for various types of window

Window area as a percentage of total floor area of room[1]															Single glazing	Double glazing of indicated glass thickness					Triple glazing			
4	5	6	8	10	13	16	20	25	32	40	50	63	80		2 mm & 2 mm glass	3 mm & 3 mm glass	4 mm & 4 mm glass	3 mm & 6 mm glass	6 mm & 6 mm glass	3 mm, 3 mm & 3 mm glass		3 mm, 3 mm and 6 mm glass	
Acoustic Insulation Factor (AIF)[2]															Thickness	Interpane spacing in mm[3]					Interpane spacings in mm[5]			
35	34	33	32	31	30	29	28	27	26	25	24	23	22		2 mm	6								
36	35	34	33	32	31	30	29	28	27	26	25	24	23			13								
37	36	35	34	33	32	31	30	29	28	27	26	25	24		3 mm	15	6							
38	37	36	35	34	33	32	31	30	29	28	27	26	25		4 mm–6 mm	18	13	6						
39	38	37	36	35	34	33	32	31	30	29	28	27	26			22	16	13	6	6	6	6		
40	39	38	37	36	35	34	33	32	31	30	29	28	27		9 mm[4]	28	20	16	13	13	6	10	6	6
41	40	39	38	37	36	35	34	33	32	31	30	29	28			35	25	20	16	16	6	15	6	10
42	41	40	39	38	37	36	35	34	33	32	31	30	29		12 mm[4]	42	32	25	20	20	6	20	6	15
43	42	41	40	39	38	37	36	35	34	33	32	31	30			50	40	32	25	24	6	30	6	20
44	43	42	41	40	39	38	37	36	35	34	33	32	31			63	50	40	32	30	6	40	6	30
45	44	43	42	41	40	39	38	37	36	35	34	33	32			80	63	50	40	37	6	50	6	40
46	45	44	43	42	41	40	39	38	37	36	35	34	33			100	80	63	55	50	6	65	6	50
47	46	45	44	43	42	41	40	39	38	37	36	35	34			125	100	80	75	70	6	80	6	65
48	47	46	45	44	43	42	41	40	39	38	37	36	35			150	125	100	95	90	6	100	6	80
49	48	47	46	45	44	43	42	41	40	39	38	37	36				150	125	100	100			6	100
50	49	48	47	46	45	44	43	42	41	40	39	38	37					150	135	125				

Source : National Research Council, Division of Building Research, June 1980

Explanatory Notes :

1) Where the calculated percentage window area is not presented as a column heading, the nearest percentage column in the table values should be used.
2) AIF data listed in the table are for well-fitted, weatherstripped units that can be opened. The AIF values apply only when the windows are closed. For windows fixed and sealed to the frame, add three (3) to the AIF given in the table.
3) If the interpane spacing or glass thickness for a specific double-glazed window is not listed in table, the nearest listed values should be used.
4) The AIF ratings for 9 mm and 12 mm glass are for laminated glass only; for solid glass, subtract two (2) from the AIF values listed in the table.
5) If the interpane spaces for a specific triple-glazed window are not listed in the table, use the listed case whose combined spacings are nearest to the actual combined spacing.
6) The AIF data listed in the table are for typical windows, but details of glass mounting, window seals, etc., may result in slightly different performance for some manufacturers' products. If laboratory sound transmission loss data (conforming to ASIM test method E-90) are available, these should be used to calculate the AIF.
7) For easy reference, glazing dimensions are written in the form 2 (100) 2 to denote 2 mm glass (100 mm space) 2 mm glass in the examples.

Table 6.3 - Acoustic Insulation Factor for Various Types of Exterior Wall

Percentage of exterior wall area to total floor area of room											Type of Exterior Wall
	16	20	25	32	40	50	63	80	100	125	160	
Acoustic Insulation Factor	39	38	37	36	35	34	33	32	31	30	29	EW1
	41	40	39	38	37	36	35	34	33	32	31	EW2
	44	43	42	41	40	39	38	37	36	35	34	EW3
	47	46	45	44	43	42	41	40	39	38	37	EW4
	48	47	46	45	44	43	42	41	40	39	38	EW1R
	49	48	47	46	45	44	43	42	41	40	39	EW2R
	50	49	48	47	46	45	44	43	42	41	40	EW3R
	55	54	53	52	51	50	49	48	47	46	45	EW5
	56	55	54	53	52	51	50	49	48	47	46	EW4R
	58	57	56	55	54	53	52	51	50	49	48	EW6
	59	58	57	56	55	54	53	52	51	50	49	EW7 or EW5R
	63	62	61	60	59	58	57	56	55	54	53	EW8

Source : National Research Council, Division of Building Research, December 1980.

Explanatory Notes :

1) Where the calculated percentage wall area is not presented as a column heading, the nearest percentage column in the table should be used.
2) The common structure of walls EW1 to EW5 is composed of 12.7 mm gypsum board, vapour barrier, and 38 x 89 mm studs with 50 mm (or thicker) mineral wool or glass fibre batts in inter-stud cavities.
3) EW1 denotes exterior wall as in Note 2), plus sheathing, plus wood siding or metal siding and fibre backer board.
   EW2 denotes exterior wall as in Note 2), plus rigid insulation (25-30 mm), and wood siding or metal siding and fibre backer board.
   EW3 denotes simulated mansard with structure as in Note 2), plus sheathing, 28 x 89 mm framing, sheathing, and asphalt roofing material.
   EW4 denotes exterior wall as in Note 2), plus sheathing and 20 mm stucco.
   EW5 denotes exterior wall as in Note 2), plus sheathing, 25 mm air space, 100 mm brick veneer.
   EW6 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25-50 mm), 100 mm back-up block, 100 mm face brick.
   EW7 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25-50 mm), 140 mm back-up block, 100 mm face brick.
   EW8 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25-50 mm), 200 mm concrete.
4) R signifies the mounting of the interior gypsum board on resilient clips.
5) An exterior wall conforming to rainscreen design principles and composed of 12.7 mm gypsum board, 100 mm concrete block, rigid insulation (25-50 mm), 25 mm air space, and 100 mm brick veneer has the same AIF as EW6.
6) An exterior wall described in EW1 with the addition of rigid insulation (25-50 mm) between the sheathing and the external finish has the same AIF as EW2.

Table 6.4 - Acoustic Insulation Factor for Various Types of Exterior Door

	Percentage of total door area to total floor area of room									Type of Exterior Door
	4	5	6.3	8	10	12.5	16	20	25	
Acoustic	30	29	28	27	26	25	24	23	22	D1
Insulation	34	33	32	31	30	29	28	27	26	D2
Factor	36	35	34	33	32	31	30	29	28	D3
	37	36	35	34	33	32	31	30	29	D4
	38	37	36	35	34	33	32	31	30	D5 or D1-sd
	41	40	39	38	37	36	35	34	33	D2-sd
	43	43	41	40	39	38	37	36	35	D3-sd
	44	43	42	41	40	39	38	37	36	D4-sd
	45	44	43	42	41	40	39	38	37	D5-sd
	48	47	46	45	44	43	42	41	40	D3-D3
	50	49	48	47	46	45	44	43	42	D5-D5

Source: National Research Council, Division of Building Research, December 1980.

Explanatory Notes:

1) Where the calculated percentage door area is not presented as a column heading, the nearest percentage column in the table should be used.
2) All prime doors must be fully weatherstripped.
3) D1 denotes 45 mm hollow core wood door (up to 20% of area glazed).
   D2 denotes 45 mm glass-fibre reinforced plastic door with foam or glass-fibre insulated core (up to 20% of area glazed).
   D3 denotes 35 mm in solid slab wood door.
   D4 denotes 45 mm steel door with foam or glass-fibre insulated core.
   D5 denotes 45 mm solid slab door.
4) sd denotes storm door of wood or aluminum with openable glazed sections. The AIF values apply when the glazed sections are closed.

Table 6.5 - Component area percentages relative to total floor area of a room

Total area of windows, or doors, or exterior walls in square metres	Total floor area of room in square metres													
	2.7 to 3.2	3.3 to 4.1	4.2 to 5.2	5.3 to 6.6	6.7 to 8.3	8.4 to 10.4	10.5 to 13.0	13.1 to 16.6	16.7 to 20.8	20.9 to 26.0	26.1 to 33.1	33.2 to 41.3	41.4 to 52.1	52.2 to 65.7	65.8 to 88.3
0.42 to 0.52	16	12.5	10	8	6.3	5	4								
0.53 to 0.66	20	16	12.5	10	8	6.3	5	4							
0.67 to 0.83	25	20	16	12.5	10	8	6.3	5	4						
0.84 to 1.04	32	25	20	16	12.5	10	8	6.3	5	4					
1.05 to 1.30	40	32	25	20	16	12.5	10	8	6.3	5	4				
1.31 to 1.67	50	40	32	25	20	16	12.5	10	8	6.3	5	4			
1.68 to 2.04	63	50	40	32	25	20	16	12.5	10	8	6.3	5	4		
2.1 to 2.6	80	63	50	40	32	25	20	16	12.5	10	8	6.3	5	4	
2.7 to 3.2	100	80	63	50	40	32	25	20	16	12.5	10	8	6.3	5	4
3.3 to 4.1	125	100	80	63	50	40	32	25	20	16	12.5	10	8	6.3	5
4.2 to 5.2	160	125	100	80	63	50	40	32	25	20	16	12.5	10	8	6.3
5.3 to 6.6		160	125	100	80	63	50	40	32	25	20	16	12.5	10	8
6.7 to 8.3			160	125	100	80	63	50	40	32	25	20	16	12.5	10
8.4 to 10.4				160	125	100	80	63	50	40	32	25	20	16	12.5
10.5 to 13.0					160	125	100	80	63	50	40	32	25	20	16
13.1 to 16.6						160	125	100	80	63	50	40	32	25	20
16.7 to 20.8							160	125	100	80	63	50	40	32	25
20.9 to 26.0								160	125	100	80	63	50	40	32
26.1 to 33.1									160	125	100	80	63	50	40
33.2 to 41.3										160	125	100	80	63	50
41.4 to 51.2											160	125	100	80	63

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Appendix A

Graphical Procedure for Noise Level Prediction

Source Characteristics of Road Traffic Noise (See Part 3)

The noise level at a distance of 30 m from the centreline of a straight level road can be determined from Fig. A.1. This figure gives the noise level for several common traffic speeds as a function of the effective number of vehicles (N_{eff}), given by:

$$N_{eff} = N\left[1 + x\ (t - 1)\right]$$

Where N is the total number of vehicles /24 hours:

x is the fraction of N that are heavy vehicles

t is the coefficient taken from Table A.1

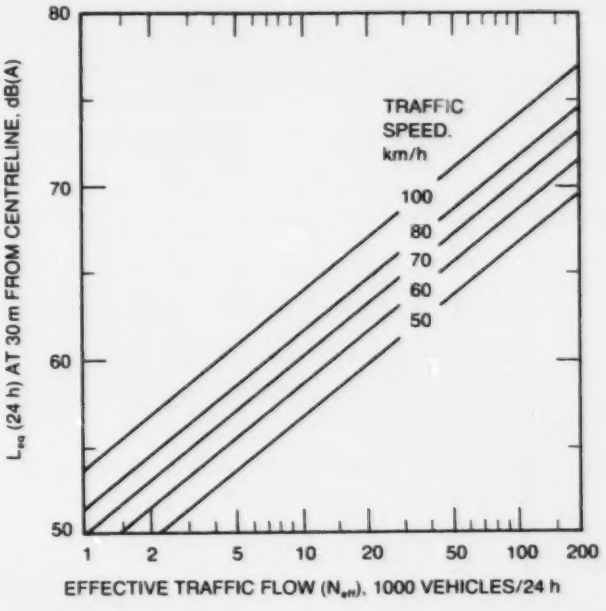


FIGURE A.1
PREDICTED EQUIVALENT SOUND LEVEL (L_{eq} (24 h)) AT 30m FROM CENTRELINE (BEFORE CORRECTIONS)

Table A.1: Values of t for Common Traffic Speeds

Traffic Speeds (km/h)	Value of t
40	21
50	18
60	16
70	14
80 or greater	13

The source level may be modified by the corrections given in Fig. A.2 and Table A.2 if a gradient or nearby stop are present.

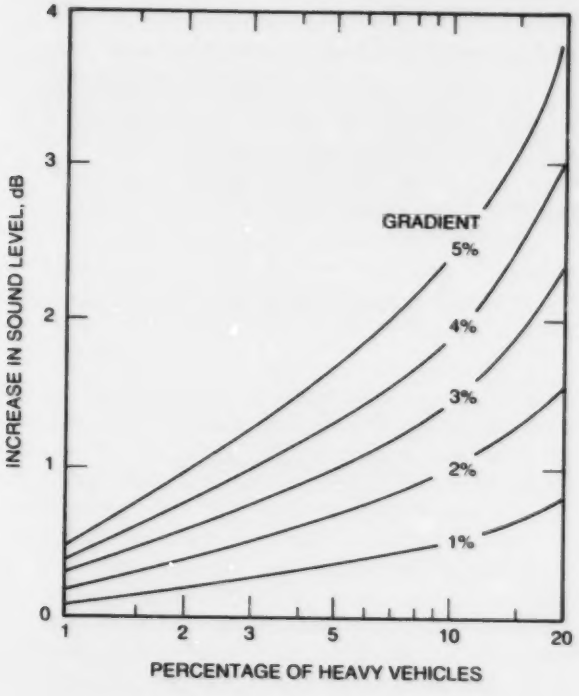
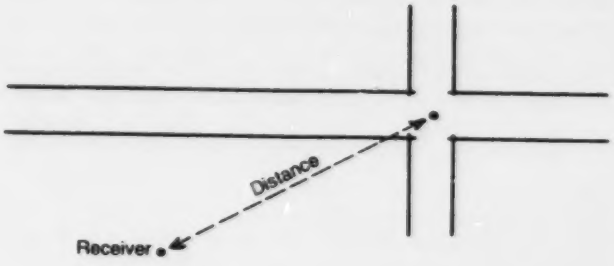


FIGURE A.2

CORRECTION TO PREDICTED EQUIVALENT SOUND LEVEL (L_{eq} (24 h)) TO ALLOW FOR ROAD GRADIENTS

Table A.2: Correction (in dB) to be added for interrupted traffic flow

Distance from Intersection to Receiver (Metres)	Correction (in dB)
0 - 60	2
60 - 150	1
Over 150	0



To calculate other corrections to the noise level, it is necessary to determine the height of the noise source above the road. Light vehicles are treated as a single source 0.3 m above the road surface, whereas heavy vehicles are viewed as two sources — tire noise at 0.3 m and engine noise at 2.5 m above the surface. These sources have different speed dependencies, so a single equivalent source level, which is a function of both speed and percentage of heavy vehicles, has been given in Fig. A.3.

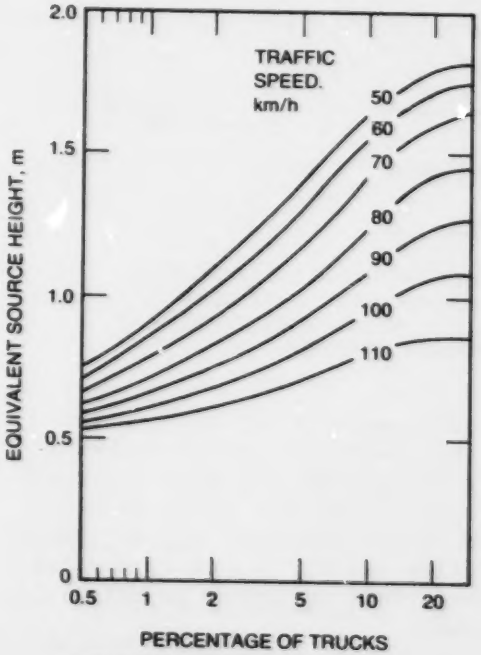


FIGURE A.3

EQUIVALENT HEIGHT OF TRAFFIC NOISE SOURCE FOR VARIOUS TRAFFIC FLOW CONDITIONS

Source Characteristics of Railway Traffic Noise (See Part 4)

The wheel-rail noise at 30 m as a function of the number of railway cars per 24 hours is given in Fig. A.4 for a range of train speeds. The graph is applicable to typical jointed rails in good condition; for continuous welded rails, the predicted values should be decreased by 3 dB. The noise source is taken to be 0.5 m above the track.

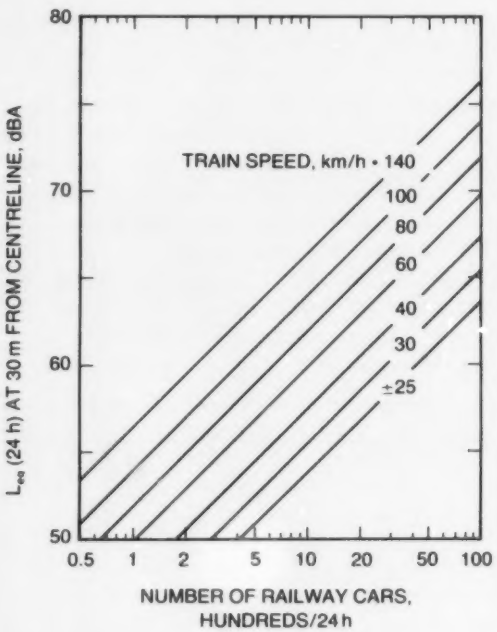


FIGURE A.4

PREDICTED EQUIVALENT SOUND LEVEL FROM WHEEL-RAIL INTERACTION (L_{eq} (24 h)) AT 30 m FROM CENTRELINE (BEFORE CORRECTIONS)

Engine noise depends not only on the train speed, but also on the number of cars per locomotive. In Fig. A.5 the engine noise at 30 m is given as a function of the number of locomotives per day, for several values of the load parameter. This parameter is calculated as follows:

load parameter =

$$0.15C + 13.5 (\log S) + 2.5$$

where C is the average number of railway cars per locomotive and S is the train speed in kilometres per hour. Locomotive noise is taken to be at a source height of 4 m above the track.

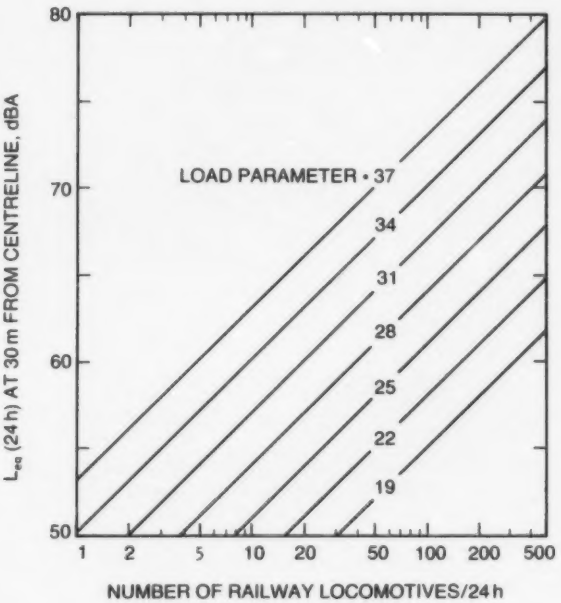


FIGURE A.5

PREDICTED EQUIVALENT SOUND LEVEL FROM RAILWAY LOCOMOTIVES (L_{eq} (24 h)) AT 30 m FROM CENTRELINE (BEFORE CORRECTIONS)

These procedures will not give valid results for special cases, such as switching yards, tight radius curves (radius less than 200 m), or a railway elevated on a trestle.

If a level crossing at which a whistle is sounded is present, then this must be treated as in step 6 of Part 4.

Noise Propagation

Having determined the basic noise level at a reference distance of 30 m from the centreline of the roadway or railway, corrections must be made for the actual source to receiver distance.

With hard ground, a decrease of 3 dB can be expected for each doubling of the distance, but where the surface is covered with grass or other plants, a further reduction may take place because of ground attenuation.

Raising the source appreciably above the surface, or other changes that raise the propagation path, also reduce the ground attenuation; this is dealt with by the concept of an "effective total height", which for level ground is equal to the sum of the source and receiver heights. As illustrated in Fig. A.6, this is based on the premise that the angle between the reflected ray and the surface is the most important parameter determining the ground attenuation.

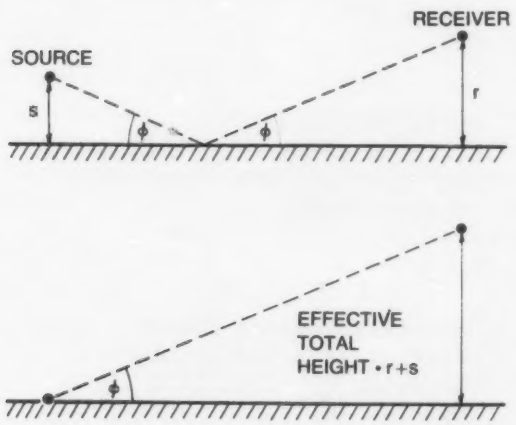
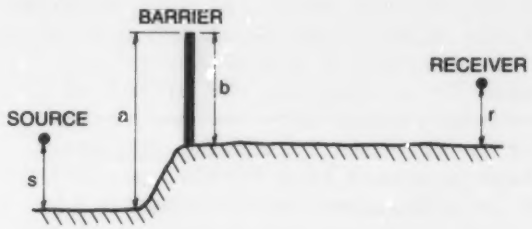


FIGURE A.6

DETERMINING EFFECTIVE TOTAL HEIGHT FOR GROUND ATTENUATION CALCULATIONS

Where a barrier or other obstruction interferes with the sound waves reflected from the surface, a marked reduction in ground attenuation can be expected. Fig. A.7 shows how this can be dealt with by using an extension of the effective total height concept.



EFFECTIVE TOTAL HEIGHT = s+a+b+r

FIGURE A.7

DETERMINING EFFECTIVE TOTAL HEIGHT FOR GROUND ATTENUATION CALCULATIONS WHEN A BARRIER IS IN PLACE

The resulting effective total height and the horizontal source to receiver distance can then be used to obtain the ground attenuation from Fig. A.8 (See Tables 3.5 and 4.7).

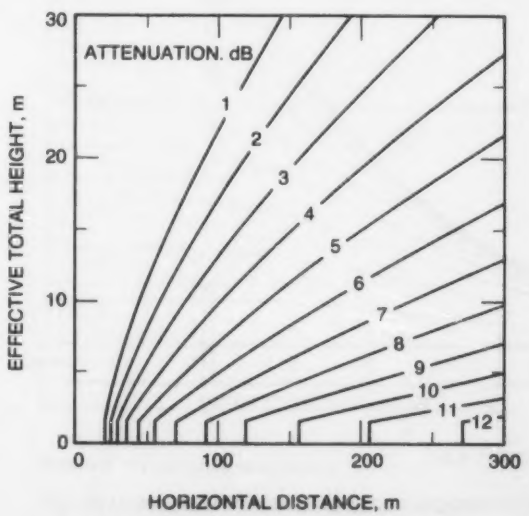


FIGURE A.8

CORRECTION TO PREDICTED EQUIVALENT SOUND LEVEL (L_{eq}) TO ALLOW FOR GROUND ATTENUATION

Barriers

The predicted noise attenuation provided by an infinitely long barrier can be determined by the procedure given in Appendix B.

In practice, the attenuation provided by a barrier is often limited by noise coming around one or both ends. Because barriers are seldom symmetrical about the receiving point of interest, a set of curves appropriate for evaluating the effect of sound coming around only one end of the barrier is given in Fig. A.9. The attenuation provided by a barrier of finite length in both directions is obtained by correcting first for the short end of the barrier and then using that adjusted attenuation as the nominal barrier attenuation when calculating the correction for the other end. The curves in Fig. A.9 show the attenuation as a function of the "barrier aspect ratio"; calculation of this ratio is illustrated in Fig. A.10.

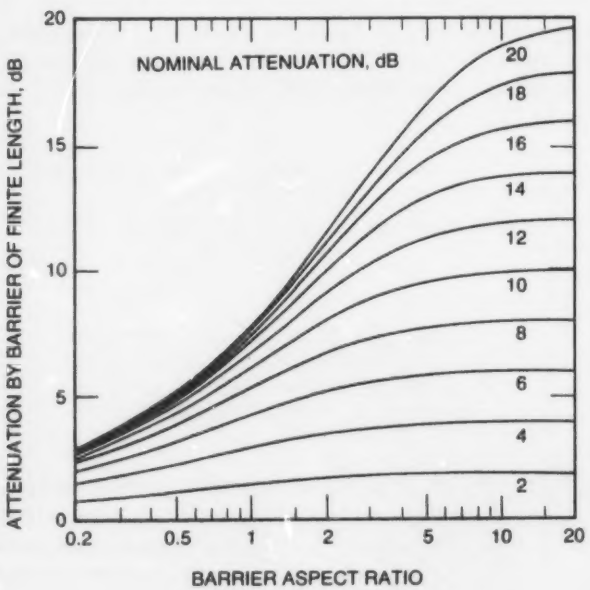


FIGURE A.9

CORRECTION TO THE BARRIER ATTENUATION TO ALLOW FOR SOUND COMING AROUND ONE END

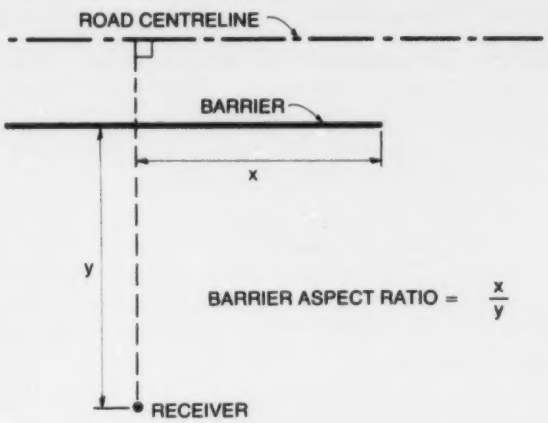


FIGURE A.10

DETERMINING THE "BARRIER ASPECT RATIO" FOR ONE END OF A BARRIER

References:

National Research Council, Division of Building Research, Building Research Note 146, (March 1980).

National Research Council, Division of Building Research, DBR Paper No. 875, NRCC 17942, (October 1979).

National Research Council, Division of Building Research, DBR Paper No. 876, NRCC 17943, (October 1979).

Appendix B — Barrier Considerations

Exact Calculation of Barrier Attenuation

The theoretical basis of this barrier attenuation calculation is the point source theory of Maekawa, as modified by Kurtze and Anderson, for a line source and barrier of infinite length. An approximation to this, also shown in Fig. B.3, can be formulated as:

Equation B1

Barrier attenuation

= 20 dB
for $d > 6$ m

= $7.7 \log d + 14$ dB
for $0.3 \text{ m} < d \leq 6$ m

= $-10.4\,(d+0.06) + 22.8\sqrt{(d+0.06)}$ dB
for $0 \leq d \leq 0.3$ m

if the barrier interrupts the line of sight, and as

Equation B2

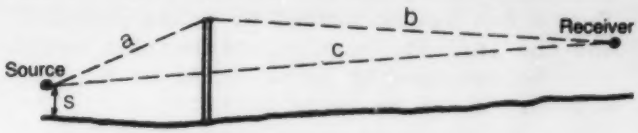
Barrier attenuation

= $-10.4\,(0.06-d) + 22.8\sqrt{(0.06-d)}$ dB
for $0 \leq d \leq 0.06$ m

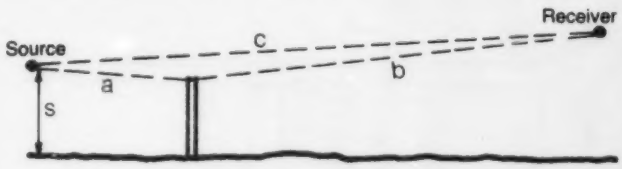
= 0
for $d > 0.06$ m

if the barrier does not interrupt the line of sight. In both cases "d" is the difference (in metres) between the limiting path from the source to the top of the barrier to the receiver and the direct path from the source to the receiver. Referring to Fig. B.1

Equation B3 $d = a + b - c$



Barrier interrupts line of sight



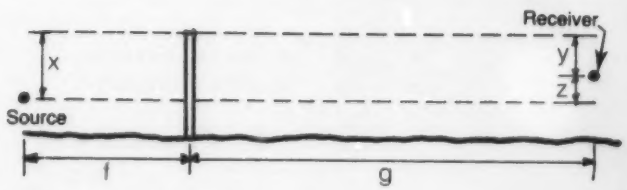
Barrier nearly interrupts line of sight

Fig. B1 — Basic barrier model (vertical section)

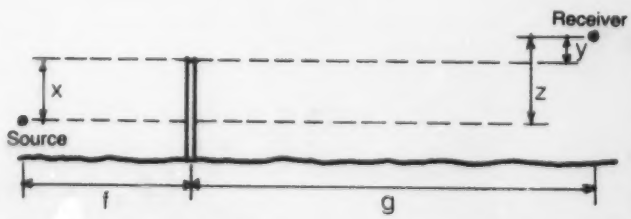
If an accurate scale drawing is available, these lengths may be measured directly, but the difference, d, must be known to within 10%. Alternatively, it can be determined in terms of the dimensions shown in Fig. B.2.

$$a = \sqrt{f^2 + x^2} \qquad b = \sqrt{g^2 + y^2}$$

$$c = \sqrt{(f+g)^2 + z^2}$$



Receiver below barrier



Receiver above barrier and source

Fig. B2 — Necessary dimensions for calculation of barrier attenuation

Thus d can be determined by using Eq B3, and the infinite-barrier attenuation could then be obtained by using Eq B1 or B2. However, d can be taken directly to Table 3.7 for Road Traffic or Table 4.6 for Rail Traffic, both of which give the barrier attenuation for a finite barrier.

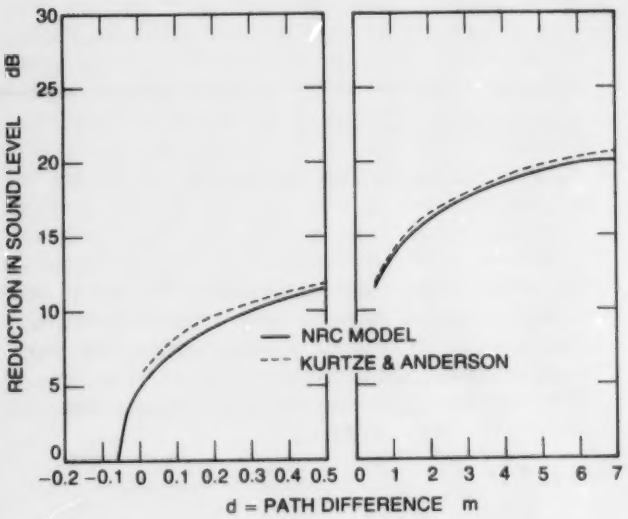


FIGURE B.3
PREDICTED REDUCTION IN L_{∞} PROVIDED BY A BARRIER OF INFINITE LENGTH

Although in principle the barrier attenuation continues to increase indefinitely with increasing path difference, in practice various fringe effects, such as atmospheric refraction and extraneous reflections, tend to limit the reduction that can be realized by a barrier. Hence the maximum allowable barrier attenuation is set at 20 dB. Even below 20 dB, care must be taken to avoid major reflections reaching the receiving point from nearby buildings.

Sample Barrier Calculations

The example shown in Figs. 3f and 4f in Parts 3 and 4 has already been used as a numerical example to illustrate the calculations. Example Ref. Nos. B1 to B5 show other barrier configurations and the associated calculations for determining the barrier insertion loss. Example B3 illustrates the calculation for a sheltered outdoor area screened by row housing.

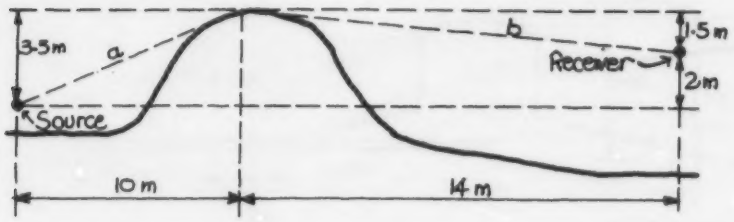
In the overall calculation of noise levels, the barrier attenuation is subtracted from the level determined for propagation over hard or soft terrain, as in Step 6 of Section B, Part 3. Note that for propagation over soft terrain, the presence of the barrier must be taken into account, as is indicated in Table 3.5 and the corresponding Table 4.4 in Part 4.

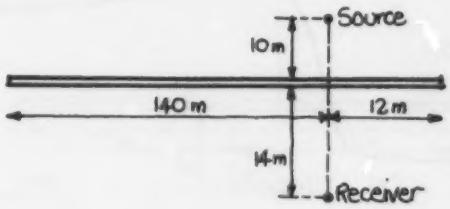
Calculation Sheet B - Barrier attenuation

Use of a berm as a barrier

Reference No. B.1

Date: _____





This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

   Horizontal distance (f) is 10.00 m: squared value = 100.00 m^2
   Vertical distance (x) is 3.50 m: squared value = 12.25 m^2
   Sum of squared values is 112.25 m^2
   Square root of sum is 10.59 m = distance a

2. Distance b (barrier top to receiver)

   Horizontal distance (g) is 14.00 m: squared value = 196.00 m^2
   Vertical distance (y) is 1.50 m: squared value = 2.25 m^2
   Sum of squared values is 198.25 m^2
   Square root of sum is 14.08 m = distance b

3. Distance c (source to receiver)

   Horizontal distance (f+g) is 24.00 m: squared value = 576 m^2
   Vertical distance (z) is 2.00 m: squared value = 4 m^2
   Sum of squared values is 580 m^2
   Square root of sum is 24.08 m = distance c

4. Path length difference is a+b-c = 0.59 m

   (✓) Barrier interrupts line of sight
   ( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

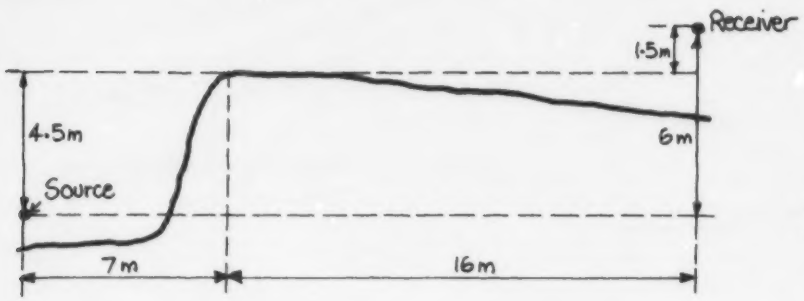
   Barrier to receiver distance (g) = 14 m
   Length of barrier segment (u) = 12 m: ratio u/g = 0.85
   Length of barrier segment (v) = 140 m: ratio v/g = 10.00

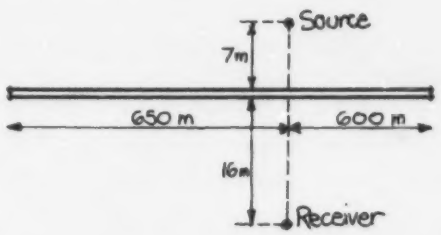
   From table 3.6, effective barrier length ratio w = 1.5

6. From table 3.7, barrier attenuation = 6 dB.

Calculation Sheet B - Barrier attenuation Reference No. B.2

Change in grade used as a barrier, receiver higher than source Date: _____





This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is	7.00 m:	squared value =	49.00 m^2_2
Vertical distance (x) is	4.50 m:	squared value =	20.25 m^2_2
Sum of squared values is			69.25 m^2
Square root of sum is	8.32 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	16.00 m:	squared value =	256.00 m^2_2
Vertical distance (y) is	1.50 m:	squared value =	2.25 m^2_2
Sum of squared values is			258.25 m^2
Square root of sum is	16.07 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	23.00 m:	squared value =	529 m^2_2
Vertical distance (z) is	6.00 m:	squared value =	36 m^2_2
Sum of squared values is			565 m^2
Square root of sum is	23.77 m	= distance c	

4. Path length difference is a+b-c = 0.62 metres

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

Barrier to receiver distance (g) = 16 m
Length of barrier segment (u) = 600 m: ratio u/g = 34.50
Length of barrier segment (v) = 660 m: ratio v/g = 40.62

From table 3.6, effective barrier length ratio w = Infinite

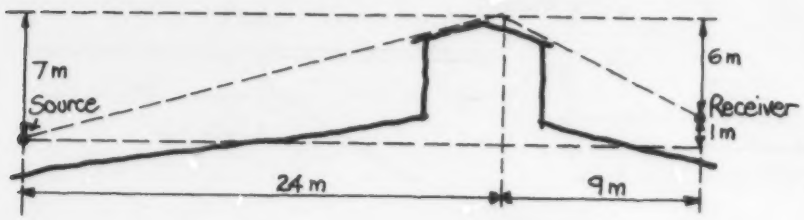
6. From table 3.7, barrier attenuation = 12 dB.

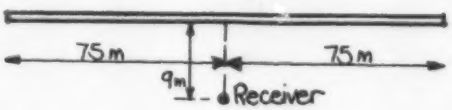
Calculation Sheet B - Barrier attenuation

Use of building as a barrier

Reference No. B.3

Date: _____





This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is 24 m: squared value = 576 m^2
Vertical distance (x) is 7 m: squared value = 49 m^2
Sum of squared values is 625 m^2
Square root of sum is 25 m = distance a

2. Distance b (barrier top to receiver)

Horizontal distance (g) is 9.00 m: squared value = 81 m^2
Vertical distance (y) is 6.00 m: squared value = 36 m^2
Sum of squared values is 117 m^2
Square root of sum is 10.82 m = distance b

3. Distance c (source to receiver)

Horizontal distance (f+g) is 33.02 m: squared value = 1089 m^2
Vertical distance (z) is 1.00 m: squared value = 1 m^2
Sum of squared values is 1090 m^2
Square root of sum is 33.00 m = distance c

4. Path length difference is a+b-c = 2.80 m

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

Barrier to receiver distance (g) = 9 m
Length of barrier segment (u) = 75 m: ratio u/g = 8.33
Length of barrier segment (v) = 75 m: ratio v/g = 8.33

From table 3.6, effective barrier length ratio w = 8

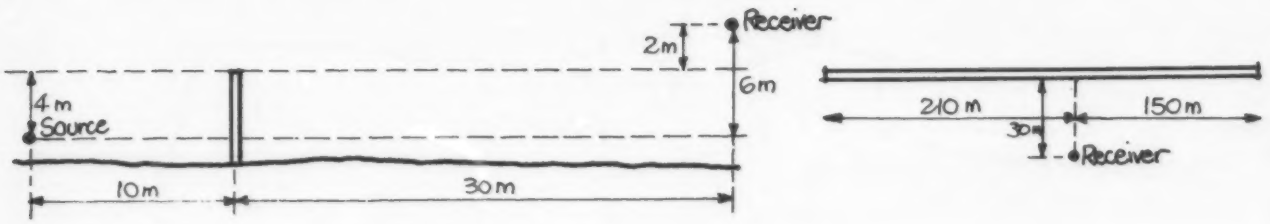
6. From table 3.7, barrier attenuation = 15 dB.

Calculation Sheet B - Barrier attenuation

Reference No. B.4

Wall or fence used as a barrier

Date: _____



This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is	10.00 m:	squared value =	100 m^2
Vertical distance (x) is	4.00 m:	squared value =	16 m^2
Sum of squared values is			116 m^2
Square root of sum is	10.77 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	30.00 m:	squared value =	900 m^2
Vertical distance (y) is	2.00 m:	squared value =	4 m^2
Sum of squared values is			904 m^2
Square root of sum is	30.06 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	40.00 m:	squared value =	1600 m^2
Vertical distance (z) is	6.00 m	squared value =	36 m^2
Sum of squared values is			1636 m^2
Square root of sum is	40.45 m	= distance c	

4. Path length difference is a+b-c = 0.38 m

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

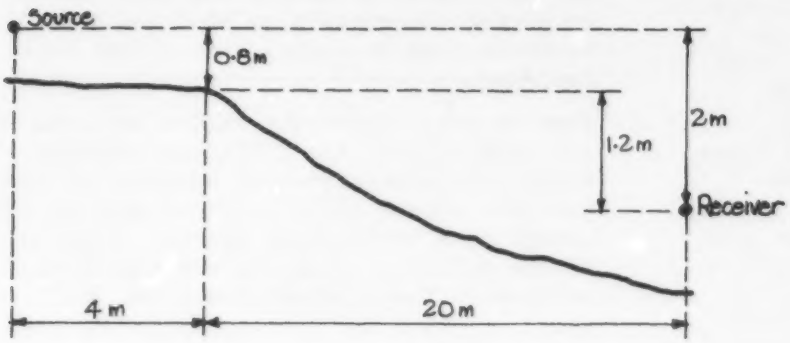
Barrier to receiver distance (g) = 30 m
Length of barrier segment (u) = 150 m: ratio u/g = 5
Length of barrier segment (v) = 210 m: ratio v/g = 7

From table 3.6, effective barrier length ratio w = 6

6. From table 3.7, barrier attenuation = 11 dB.

Calculation Sheet B - Barrier attenuation Reference No. B.5

Change in grade used as a barrier, source higher than receiver Date: _____



This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is	4.0 m:	squared value =	16.00 m^2
Vertical distance (x) is	0.8 m:	squared value =	0.64 m^2
Sum of squared values is			16.64 m^2
Square root of sum is	4.08 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	20.0 m:	squared value =	400.00 m^2
Vertical distance (y) is	1.2 m:	squared value =	1.44 m^2
Sum of squared values is			401.44 m^2
Square root of sum is	20.04 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	24.0 m:	squared value =	576 m^2
Vertical distance (z) is	2.0 m:	squared value =	4 m^2
Sum of squared values is			580 m^2
Square root of sum is	24.08 m	= distance c	

4. Path length difference is a+b-c = 0.04 m

( ) Barrier interrupts line of sight
(✓) Barrier does not interrupt line of sight

5. Plan view dimensions:

Barrier to receiver distance (g) = 20 m
Length of barrier segment (u) = 840 m: ratio u/g = 42
Length of barrier segment (v) = 1050 m: ratio v/g = 53

From table 3.6, effective barrier length ratio w = Treat as Infinite

6. From table 3.7, barrier attenuation = 2 dB.

Associated Ventilation Needs

No matter what components are selected, the difference between the outdoor and indoor noise level is unlikely to exceed 20 dB if the windows are opened to provide ventilation. For residential rooms with a window opening of 0.28 m^2 (the minimum requirement of the Canadian Residential Standards), the typical noise reduction is approximately 15 dB, depending on the size and furnishing of the room. Obviously the noise reduction can be increased by partially closing the windows, but for sites where the noise level is in excess of 55 dB, the indoor noise limits of Table 1 cannot be satisfied if the windows are opened appreciably. Although this does not pose a problem during the winter, the windows can be kept closed during the summer only if an alternative means of ventilation is provided. For most heavily populated areas in Canada, a mechanical ventilation system would have to include air conditioning to provide reasonable comfort in the warmer months.

If the noise level outside the windows is less than 55 dBA, the indoor noise criteria should be satisfied even with open windows, except that bedrooms may be marginally noisier than is desirable.

The use of the single criterion (55 dBA) to determine the need for an alternate means of ventilation must be related to indoor noise criteria based on the intended use of each room, by assigning an AIF value for ventilation openings. For a window opened to satisfy the minimum window opening (0.28 m^2) specified in Residential Standards, the AIF ratings shown in Table C.1 apply.

If the required AIF for an openable window is lower than the appropriate value in Table C.1, then an alternate means of ventilation is not required to meet the indoor noise criterion. The proviso that open windows are an acceptable means of ventilation if the outside noise is less than 55 dBA would still apply as a bottom limit.

Because the required AIF varies according to the intended use of a room, this approach provides an additional incentive for developers to locate the least noise-sensitive rooms, such as kitchens and bathrooms, on the noisy side of the building.

Even in cases where the entire building is air conditioned, the different incident noise levels at different surfaces of the building should still be considered in the design of a ventilating system, at least to the extent of locating air inlets and outlets in the quietest positions available.

In practice, the phrase "alternative means of ventilation" is normally interpreted as a requirement for air conditioning.

Where it is not mandatory, developers may not wish to include air conditioning because of the resultant increase in the selling price or rental rate. In such cases the use of a forced-air heating system with ducting appropriate for air conditioning should be encouraged. This will permit the eventual occupants to add air conditioning at a later date if they find the noise admitted by opening the windows for ventilation to be unacceptable. Even without air conditioning, such a system can partially fulfil the ventilation requirements if provisions are made to exhaust the cold air return ducts to outside and suck fresh air from outside into the cold air return plenum. To minimize noise entering through the air-handling system, the inlet and outlet ducts should be designed to provide some noise attenuation. Lining the ducts with suitable acoustical absorption material, such as ductliner glass fibre, and including at least one 90° bend in the lined segments is one way of reducing noise.

Table C.1: Acoustic Insulation Factor for Open Window

Room Floor Area (m^2)	Open Window AIF
5	9
7	10
8	11
10	12
13	13
16	14
20	15
25	16
32	17

Source: National Research Council of Canada, Division of Building Research, June 1980.

Reference: National Research Council, Division Building Research, Building Research Note 148 (Revised June 1980).

Minimum System for Mechanical Ventilation for Forced Warm Air, Fuel Fired Systems

The following system may be considered to be the minimum acceptable to provide mechanical ventilation.

Components

This system will comprise:

1. A fresh air inlet connecting the exterior to the cold air return plenum. (Minimum 150 mm diameter duct properly insulated, with regulating damper.)
2. A roof/ceiling exhaust fan or suitable alternative installation complete with damper and noise baffles. (Capacity for 3/4 air change per hour.) It is recommended that the exhaust be located on the side of the house which is least exposed to sound.
3. A furnace with a two-speed circulating fan.
4. A manual damper located between the fresh air inlet and any cold air inlet in the main cold air return duct.

Operation

Winter

Fresh air will be drawn in through fresh air inlets to make up air lost through the chimney flue and the exhaust fan. This air is heated and distributed by the heating system. The damper on the cold air return is open. The two-speed fan on the furnace will ensure continuous operation. This should provide 0.5 air change per hour.

Summer

The damper on the cold air return is closed. The furnace fan will draw air through the fresh air inlet and circulate it through the heating system. Stale air will escape through the chimney flue and the exhaust fan. For a standard furnace with a circulating fan, this should provide 0.5 air changes per hour. It is recognized that this may not be sufficient for severe summer conditions and temporary additional ventilation by means of open windows may be necessary.

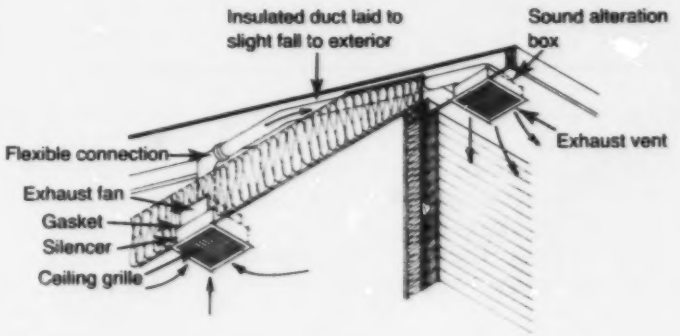


Fig. C1 : Exhaust Fan

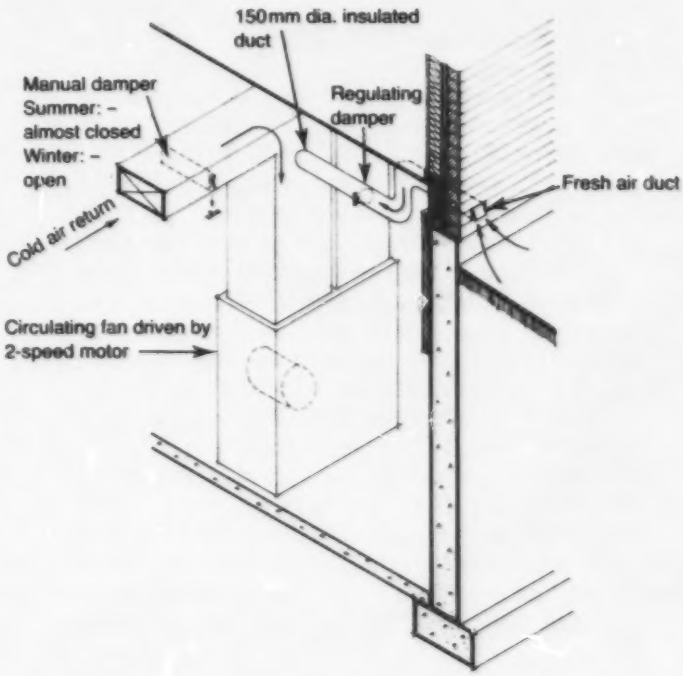

150mm dia. insulated duct
Manual damper Summer: - almost closed Winter: - open
Regulating damper
Fresh air duct
Cold air return
Circulating fan driven by 2-speed motor

Fig. C2 : Fresh Air Inlet

Appendix D

Calculating Acoustic Insulation Factor from Laboratory Data

One major problem associated with the use of AIF ratings is the need to rate components such as doors or windows which are produced by various manufacturers. Tables 6.2-6.4 list AIF ratings for a broad range of components, but obviously do not include all possible constructions. Also, some manufacturers' windows or doors may provide more acoustical insulation than "typical" components because of special design features, such as unusually good weatherstripping.

If such products have been tested in a laboratory in accordance with ASTM Method E90 for Measurement of Sound Transmission Loss, the test results can be used to calculate the AIF. A detailed procedure for calculating the AIF and a method for estimating the AIF from a laboratory Sound Transmission Class (STC) are presented below.

Detailed Calculation Procedure

The difference between the outdoor A-weighted noise level and the resulting indoor level depends on both the transmission loss characteristic of the component and the spectral content of the noise source.

The source spectrum used for AIF calculations is given in Table D1; it is normalized to approximately 80 dBA to provide a convenient range of values for the calculation. By subtracting the Sound Transmission Loss values from the A-weighted source sound levels, the corresponding A-weighted indoor sound levels in each 1/3-octave band are obtained. Combining these 1/3-octave band levels yields the overall A-weighted sound level that would be measured in a room if only that component were transmitting sound and the component area were equal to the acoustical absorption (typically 80% of room floor area). This level is subtracted from 77 dBA (a value obtained by combining the 1/3-octave band source levels and correcting to allow for differences between the source sound field at an exterior facade and that in laboratory test chambers, as discussed in the reference). This gives the AIF for component area equal to 80% of room floor area. For other percentages (P) of component area relative to floor area, the AIF may be calculated by subtracting 10 log (P/80) from the AIF value for 80 percent. The calculated values should be rounded to the nearest integer.

The calculation procedure is illustrated by the example given in the worksheet in Fig. D1.

Estimating the Acoustic Insulation Factor from STC

In some cases a manufacturer or his agent may know the STC of a product, but be unable to provide the 1/3-octave band sound transmission loss data. This should not occur, because in order to determine the STC, one must first obtain the sound transmission loss data for the 1/3-octaves from 125 Hz to 4000 Hz. Laboratory reports of STC determinations consistent with the ASTM standard E413 should include this information.

If detailed sound transmission loss data are not available, the AIF can be estimated from the STC value, using Table D2 for doors and windows, or Table D3 for walls. Because the estimate tends to give slightly lower values for the AIF than are obtained from the detailed calculations, it is usually to a manufacturer's advantage to use the detailed calculation procedure.

Reference: *Acoustic Insulation Factor: A Rating for the Insulation of Building Against Outdoor Noise*, National Research Council, Division of Building Research. Building Research Note 148 (revised June 1980).

Table D1 : Standard source spectrum for calculating Acoustic Insulation Factor (AIF)

Frequency (Hz)	Source Sound Pressure Level	A-weighted Source Sound Pressure Level
100	66.1	47
125	69.1	53
160	71.4	58
200	71.9	61
250	71.6	63
315	71.6	65
400	71.8	67
500	71.2	68
630	70.9	69
800	70.8	70
1000	70.0	70
1250	69.4	70
1600	69.0	70
2000	68.8	70
2500	68.7	70
3150	67.8	69
4000	67.0	68
5000	65.5	66

Note: Values in the second and third columns of this table are 1/3-octave band sound pressure levels expressed in dB.

Table D2 : Approximate conversion from STC to AIF for windows and doors

Window (or door) area expressed as percentage of room floor area	Acoustic Insulation Factor (AIF)
80	STC-5
63	STC-4
50	STC-3
40	STC-2
32	STC-1
25	STC
20	STC+1
16	STC+2
12.5	STC+3
10	STC+4
8	STC+5
6.3	STC+6
5	STC+7
4	STC+8

Note: For area percentages not listed in the table, use the nearest listed value.

Examples: For a window whose area = 20% of the room floor area and STC = 32, the AIF is 32 + 1 = 33.

For a window whose area = 60% of the room floor area and STC = 29, the AIF is 29 - 4 = 25.

Table D3 : Approximate conversion from STC to AIF for exterior walls

Exterior wall area expressed as percentage of room floor area	Acoustic Insulation Factor (AIF)
200	STC-10
160	STC-9
125	STC-8
100	STC-7
80	STC-6
63	STC-5
50	STC-4
40	STC-3
32	STC-2
25	STC-1
20	STC
16	STC+1
12.5	STC+2
10	STC+3
8	

Note: For area percentages not listed in the table, use the nearest listed value.

Examples: For a wall whose area = 120% of the room floor area and STC = 48, the AIF is 48 - 8 = 40.

Fig. D1 — Numerical Example of AIF Calculation

Frequency	A-weighted Source Sound Pressure Level (dB)	Sound Transmission Loss (dB)	A-weighted Indoor Sound Pressure Level (dB)	Energy Equivalent of Indoor (SPL)
	(A)	(B)	(C = A-B)	(D = antilog (C/10)
100	47	24	23	200
125	53	26	27	501
160	58	19	39	7943
200	61	21	40	10000
250	63	20	43	19953
315	65	20	45	31623
400	67	25	42	15849
500	68	30	38	6310
630	69	33	36	3981
800	70	37	33	1995
1000	70	39	31	1295
1250	70	41	29	794
1600	70	43	27	501
2000	70	44	26	398
2500	70	45	25	316
3150	69	43	26	398
4000	68	37	31	1259
5000	66	35	31	1259
	Sum of values in column D:			104539 = E

Calculated indoor A-weighted sound level: $10 \log_{10}(E) = \underline{50.2} = F$
AIF (component area = 80% of floor area): $(77-F) = \underline{26.8} = G$

Component Area as a Percentage of Room Floor Area	Acoustic Insulation Factor (AIF)
6.3	(G+11) = 38
8	(G+10) = 37
10	(G+ 9) = 36
12.5	(G+ 8) = 35
16	(G+ 7) = 34
20	(G+ 6) = 33
25	(G+ 5) = 32
32	(G+ 4) = 31
40	(G+ 3) = 30
50	(G+ 2) = 29
63	(G+ 1) = 28
80	(G) = 27
100	(G - 1) = 26
125	(G - 2) = 25
160	(G - 3) = 24

Appendix E

Examples of Calculations

Noise Level

In reviewing any project in relation to road and rail traffic noise, the following steps should be carried out, as applicable, in order to determine the noise level.

From a Single Road

Step 1 Obtain average traffic density, percentage of heavy vehicles and posted traffic speed

Step 2 Determine basic noise level (Tables 3.1.1 to 3.1.8)

Step 3 Apply correction for road gradient (Table 3.2)

Step 4 Apply correction for interrupted traffic flow (Table 3.3)

Step 5 Calculate equivalent source height (Table 3.4)

Step 6 Apply correction for location of receiving point relative to roadway (Table 3.5)

Step 7 Apply correction for barrier attenuation (Tables 3.6 and 3.7)

From a Single Railway

Step 1 Obtain railway use parameters: number of locomotives per day, number of rail cars per day and their average speed

Step 2 Determine the engine noise level at 30 m from track centreline, using Tables 4.1 and 4.2

Step 3 Determine the wheel-rail noise at 30 m from track centreline, using Table 4.3

Step 4 Apply correction for distance and ground surface to engine noise and wheel-rail noise (Table 4.4)

Step 5 Apply correction for barrier attenuation (Tables 4.5 and 4.6)

Step 6 Determine whistle noise if applicable (Tables 4.7 and 4.9) and apply appropriate corrections for ground attenuation (Table 4.8) or barrier attenuation (Tables 4.5 and 4.6)

From Multiple Sources

Step 1 Repeat steps 1 to 7 above as applicable for each source

Step 2 Determine combined noise level (Part 5, Table 5.1)

Sound Insulation

Having obtained the noise level at the project, the sound insulation requirements must be determined.

Step 1 Determine the exterior noise level at each wall (Part 6)

Step 2 Determine the room category (Part 6)

Step 3 Determine the number of components per room (Part 6)

Step 4 Determine the Acoustic Insulation Factor for each exterior wall of the room (Table 6.1)

Step 5 Select appropriate components from Tables 6.2, 6.3 and 6.4

Calculation Sheet A - Noise from road traffic

Project Example E.1

Description

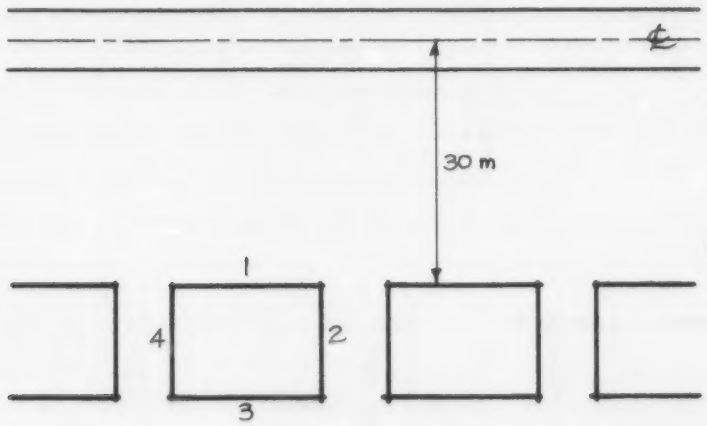
Proponent

A row of 3-bedroom bungalows is proposed at a setback of 15 m from a 30 m road allowance (i.e., 30 m from centreline). Traffic speed is 80 km/h

Reference No. E1

Date

Sketch



Daily traffic volume 4,200 vehicles 24/h

Percentage of heavy vehicles 5

Posted speed limit 80 km/h

Noise level at 30 m from centreline (Tables 3.1.1-3.1.8) 60 dB

Road gradient 2%

Percentage of heavy vehicles 5

Correction to noise level for road gradient (Table 3.2) +1 dB

Distance from intersection to receiver ____ m

Correction for interrupted flow (Table 3.3) +0 dB

Percentage of heavy vehicles 5

Posted speed limit 80 km/h

Equivalent source height 0.6 m (Table 3.4)

Distance to building line 30 m

Ground surface hard ____ or soft ✓

Effective total height 0.6 + 2 = 2.6 m (Figure 3a)

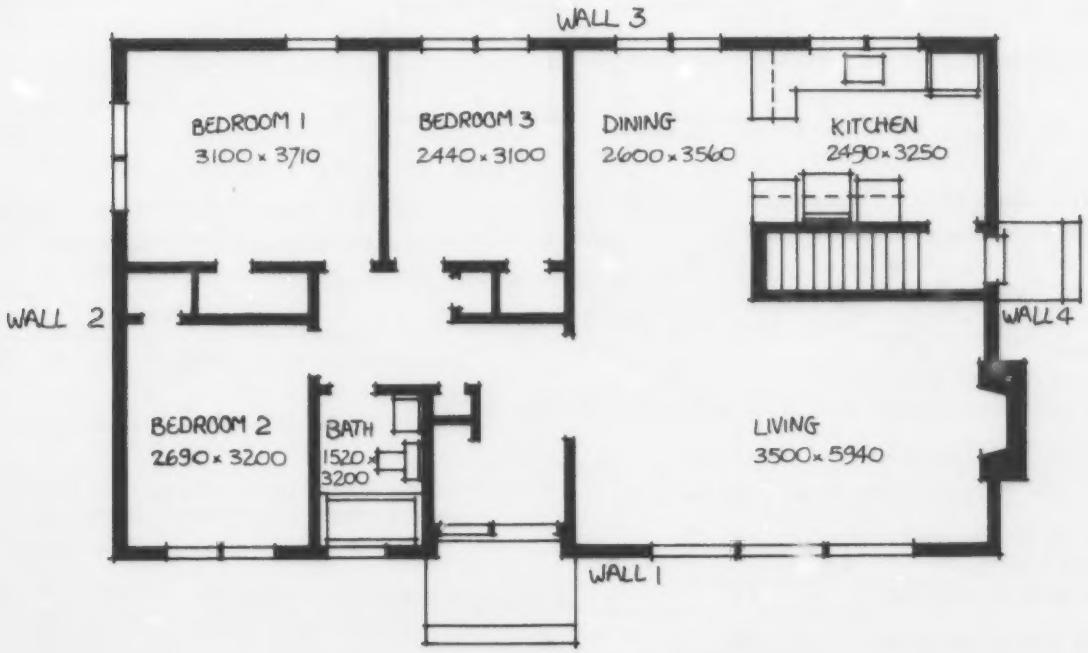
Correction for actual distance from centreline (Table 3.5) -2 dB

Correction for a barrier (Calculation Sheet B) -0 dB

Noise level reaching facade (Total of level and corrections) 59 dB

Comments on Example E.1

The allowance of 4 dB "barrier attenuation" for a row of houses, together with the reduction in noise level with increasing distance from the road, ensure that the noise in the backyards is at least 4 dB lower than the 59 dB at the front wall, and therefore satisfies the requirement for outdoor noise (55 dB). Note that if the gaps between the bungalow were blocked with noise barriers (which might include such ancillary structures as garages), the noise level in the backyards would be considerably lower.



ALL DIMENSIONS IN MILLIMETRES

Calculation Sheet D - Sound insulation needs

Reference No. Example E.1

Step 1 - Combine noise levels (See Section 5)

Date: _____

	Wall 1	Wall 2	Wall 3	Wall 4
Noise level from				
Source 1				
Source 2				
Source 3	ONLY ONE NOISE SOURCE	IMPORTANT		
Source 4				
Source 5				
Combined level	59	56	44	56

Use Table 5.1

Step 2 - Find number of components (ignore if level at wall under 55 dB)

Room	Wall 1			Wall 2			Wall 3			Wall 4			Total number of components
	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	
LIVING/DINING	✓	✓	✓								✓		4
KITCHEN							NOT				✓	✓	2
BEDROOM 1				✓	✓		COUNTED						2
" 2	✓	✓			✓		BECAUSE OUTDOOR						3
" 3							LEVEL BELOW						
BATHROOM	✓	✓					55 dB FOR THIS						2
BASEMENT				✓	✓		WALL			✓	✓		5

Step 3 - Find required AIF

LIVING/DINING	27			24
KITCHEN			NO	16
BEDROOM 1		26	AIF	
" 2	31	28	REQUIRE-	
" 3			MENT	
BATHROOM	19			
BASEMENT	23	20		20

Use Table 6.1 and number of components found above

Calculation Sheet E - Selection of components
Step 1 - Enter component areas

Reference No. Example E.1
Date:

(Only components of exterior walls are to be included in the calculation

Room	Wall 1			Wall 2			Wall 3			Wall 4			Room Floor Area
	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	
LIVING/DINING	4·4	3·2	1.2					↑			7.3		30.3
KITCHEN								NOT			5.4	1.2	8.0
BEDROOM 1				1.4	6.9		-REQUIRED-						11.5
" 2	1.6	4.4			7.4								8.6
" 3													
BATHROOM	0.7	2.3											3.1
BASEMENT		6.5		0.4	2.8			↓		0.2	2.8		93.8

Step 2 - Find component percentages (Use values from Step 1)

LIVING/DINING	16	10	4					↑			25	
KITCHEN											80	16
BEDROOM 1				12.5	63			NOT				
" 2	16	50			80		-REQUIRED-					
" 3												
BATHROOM	25	80										
BASEMENT		8						↓		4	4	

Use Table 6.5

Step 3 - Select components (Component percentages from Step 2 and AIF values from Step 3 on Sheet D)

LIVING/DINING	2(6)2	EW1	D1								EW1	
KITCHEN											EW1	D1
BEDROOM 1				2 mm	EW1							
" 2	2(15)2	EW1			EW1							
" 3												
BATHROOM	2(6)2	EW1										
BASEMENT				2mm						2 mm		

Use Tables 6.2, 6.3 & 6.4

Calculation Sheet A - Noise from road traffic

Project Example E.2

Description:

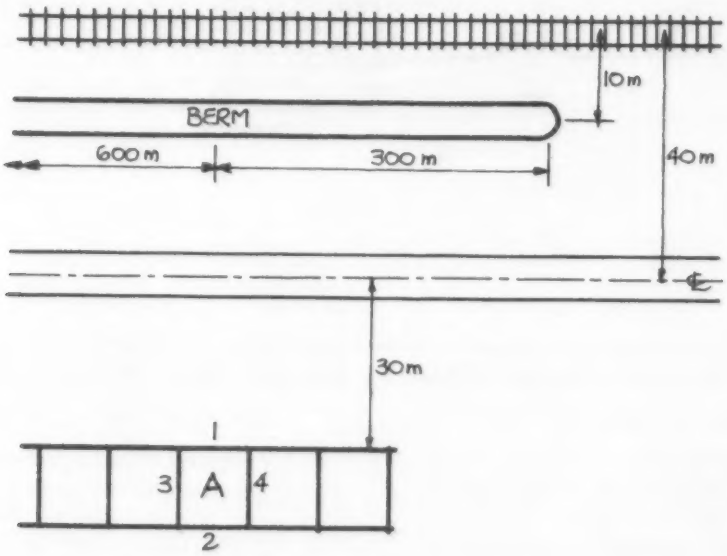
Proponent

2-storey row housing
bedrooms upstairs
calculation of level at facade of Unit A

Reference No.

Date:

Sketch

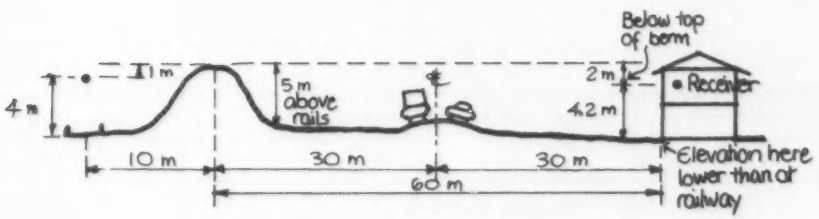


Daily traffic volume 11,000 vehicles 24 h
Percentage of heavy vehicles 8
Posted speed limit 100 km/h
Noise level at 30 m from centreline (Tables 3.1.1-3.1.8) 67 dB
Road gradient 0
Percentage of heavy vehicles 4
Correction to noise level for road gradient (Table 3.2) + 0 dB
Distance from intersection to receiver ____ m
Correction for interrupted flow (Table 3.3) + 0 dB
Percentage of heavy vehicles 8
Posted speed limit 100 km/h
Equivalent source height 0.5 m (Table 3.4)
Distance to building line 30 m
Ground surface hard ____ or soft ✓
Effective total height 4.2 + 0.5 m (Figure 3a)
Correction for actual distance from centreline (Table 3.5) - 2 dB
Correction for a barrier (Calculation Sheet B) - 0 dB
Noise level reaching facade (Total of level and corrections) 60 dB

Calculation Sheet B - Barrier attenuation
for railway engine noise

Reference No. E.2

Date: _____



This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is	10.00 m:	squared value =	100.0 m^2
Vertical distance (x) is	1.00 m:	squared value =	1.0 m^2
Sum of squared values is			101.0 m^2
Square root of sum is	10.05 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	60.00 m:	squared value =	3600.0 m^2
Vertical distance (y) is	2.00 m:	squared value =	4.0 m^2
Sum of squared values is			3604.0 m^2
Square root of sum is	60.03 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	70.00 m:	squared value =	4900.0 m^2
Vertical distance (z) is	1.00 m:	squared value =	1.0 m^2
Sum of squared values is			4901.0 m^2
Square root of sum is	70.01 m	= distance c	

4. Path length difference is a+b-c = 0.07 metres

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

Barrier to receiver distance (g) = 60 m
Length of barrier segment (u) = 300 m: ratio u/g = 5
Length of barrier segment (v) = 600 m: ratio v/g = 10

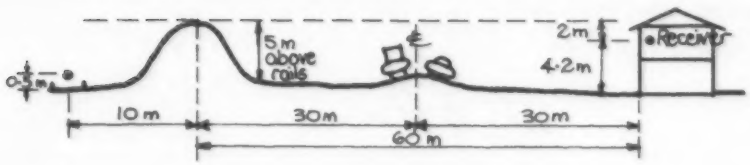
From Table 3.6, effective barrier length ratio w = 6

6. From Table 3.7, barrier attenuation = 7 dB.

Calculation Sheet B - Barrier attenuation for wheel-rail noise

Reference No. E.2

Date: _____



This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is	10.00 m:	squared value =	100.00 m^2
Vertical distance (x) is	4.50 m:	squared value =	20.25 m^2
Sum of squared values is			120.25 m^2
Square root of sum is	10.97 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	60.00 m:	squared value =	3600.0 m^2
Vertical distance (y) is	2.00 m:	squared value =	4.0 m^2
Sum of squared values is			3604.0 m^2
Square root of sum is	60.03 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	70.00 m:	squared value =	4900.00 m^2
Vertical distance (z) is	2.50 m:	squared value =	6.25 m^2
Sum of squared values is			4906.25 m^2
Square root of sum is	70.04 m	= distance c	

4. Path length difference is a+b-c = 0.96 metres

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

Barrier to receiver distance (g) = 60 m
Length of barrier segment (u) = 300 m: ratio u/g = 5
Length of barrier segment (v) = 600 m: ratio v/g = 10

From Table 3.6, effective barrier length ratio w = 6

6. From Table 3.7, barrier attenuation = 12 dB.

Calculation Sheet C1 – Railway engine noise

Reference No. E.2

Date: _____

Necessary information for average 24-hour period for each track.

Typical train speed	90	km/h
Average total number of diesel locomotives	22	
Average total number of self-powered electric cars	0	
Average total number of railway cars	1012	
Average number of trains	21	

Average total number of locomotives (D)	22		
Average total number of railway cars (n)	1012		
Average number of cars/locomotives (n/D)	46		
Noise level at 30 m for train speed 80 km/h (Table 4.1)			63 dB
Typical train speed	90	km/h	
Correction for typical train speed (Table 4.2)			+ 1 dB
Distance from source to receiving point	70	m	
Effective total height above ground using a source height of 4 m	4+5+5+4.2 = 18.2	m	
Ground surface. Hard ____ Soft ✓			
Correction for horizontal distance (Table 4.4)			- 3 dB
Barrier attenuation, if applicable, using source height of 4 m	7	dB	
Correction for barrier (minus barrier attenuation)			- 7 dB
Total engine noise level			54 dB

Calculation Sheet C2 - Wheel-rail noise

Reference No. E.2

Date: _____

Average total number of railway cars	1012	
Average total number of self-powered electric cars multiplied by two	0	
Average total number of cars	1012	
Typical train speed	90 km/h	
Noise level at 30 m (Table 4.3)		63 dB
Distance from source to receiving point	70 m	
Effective total height above ground using a source height of 0.5 m	0.5+5+4.2 = 14.7 m	
Ground surface. Hard ____ Soft ✓		
Correction for horizontal distance (Table 4.4)		- 3 dB
Barrier attenuation, if applicable, using source height of 0.5 m	12 dB	
Correction for barrier (minus barrier attenuation)		- 12 dB
Total wheel-rail noise		48 dB

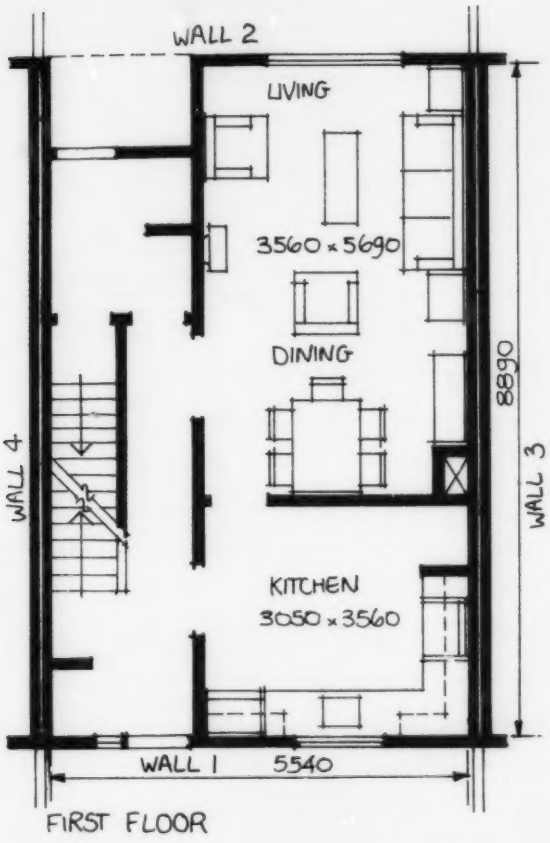
Calculation Sheet C3 - Whistle noise

Reference No. E.2

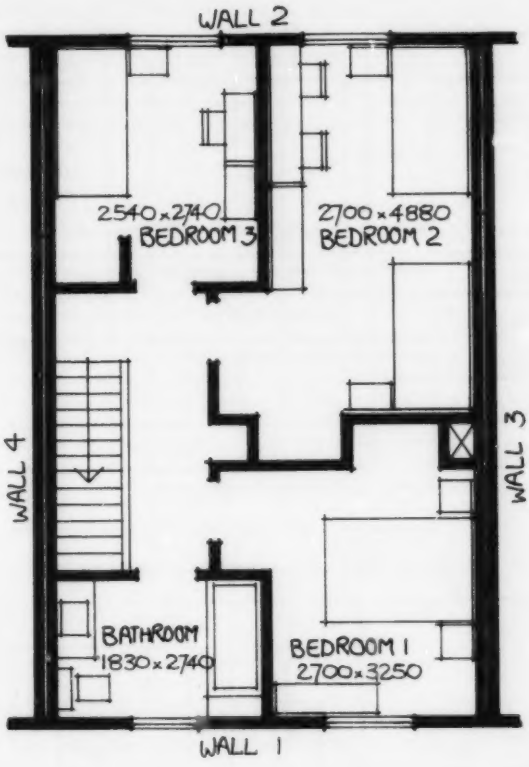
Date: _____

Shortest distance to track	_____	m	
Distance along track to warning point	_____	m	
Whistle noise for single train at: 80 km/h (Table 4.7)	_____	dB	
Average number of trains each day	_____		
Typical speed of train	_____	km/h	
Correction for number of trains and typical speed (Table 4.9)			_____ dB
Ground surface. Hard _____ Soft _____			
Shortest distance to warning zone	_____	m	
Effective total height above ground, using a source height of 4 m	_____	m	
If ground is hard, there is no correction			_____ dB
If ground is soft, correction for ground attenuation (Table 4.8)			_____ dB
Barrier attenuation if applicable, using a source height of 4 m (N.B. This calculation is modified slightly, see page 14 of text)	_____	dB	
Correction for barrier (minus barrier attenuation)			_____ dB
Total whistle noise			0 dB
The levels must be combined using Table 5.1			
Total engine noise	54	dB	
Total wheel-rail noise	48	dB	
Combined noise	55	dB	
Total whistle noise	0	dB	
Total combined noise level from railway			55 dB

N.B. This procedure must be followed for each track. The individual tracks are then combined using the same procedure.



FIRST FLOOR



SECOND FLOOR

NOTE: For bedroom 1 the necessary AIF can be achieved only with the window closed; so an alternative form of ventilation must be provided.

Consideration could therefore be given to an amended layout which would avoid locating bedrooms on the noisy side of the unit.

ALL DIMENSIONS IN MILLIMETRES

Calculation Sheet D - Sound insulation needs

Reference No. Example E.2

Step 1 - Combine noise levels (See Section 5)

	Wall 1	Wall 2	Wall 3	Wall 4
Noise level from				
Source 1	65	50	INTERNAL PARTY WALL	INTERNAL PARTY WALL
Source 2	55	40		
Source 3				
Source 4				
Source 5				
Combined level	65	50	-	-

Use Table 5.1

Step 2 - Find number of components (ignore if level at wall under 55 dB)

Room	Wall 1			Wall 2			Wall 3			Wall 4			Total number of components
	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	
LIVING/DINING					↑			↑			↑		
KITCHEN	✓	✓		NOT INCLUDED BECAUSE NOISE LEVEL IS BELOW 55 dB			NOT INCLUDED BECAUSE INTERNAL WALL			NOT INCLUDED BECAUSE INTERNAL WALL			2
HALL	✓	✓	✓										3
BATHROOM	✓	✓											2
BEDROOM 1	✓	✓											2
" 2					↓			↓			↓		
" 3													

Step 3 - Find required AIF

LIVING/DINING		↑	↑	
KITCHEN	25	NO	AIF	
HALL	27	REQUIREMENT		
BATHROOM	25			
BEDROOM 1	35			
" 2				
" 3		↓	↓	

Use Table 6.1 and number of components found above

Calculation Sheet E - Selection of Components Reference No. E.2

Step 1 - Enter component areas Date: _____

Only components of exterior walls are to be included in the calculations

Room	Wall 1			Wall 2			Wall 3			Wall 4			Room Floor Area
	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	
LIVING/DINING													
KITCHEN	0.9	7.7											10.8
HALL	0.7	1.5	1.6										14.4
BATHROOM	0.7	6.0											5.0
BEDROOM 1	1.1	5.6											8.7
" 2													
" 3													

Step 2 - Find component percentages (Use values from Step 1)

LIVING/DINING												
KITCHEN	8	63										
HALL	5	10	10									
BATHROOM	12.5	12.5										
BEDROOM 1	12.5	63										
" 2												
" 3												

Use Table 6.5

Step 3 - Select components (Component percentages from Step 2 and AIF values from Step 3 on Sheet D)

LIVING/DINING												
KITCHEN	2(6)2	EW1										
HALL	2(6)2	EW1	D2									
BATHROOM	2(6)2	EW1										
BEDROOM 1	3(20)3	EW2										
" 2												
" 3												

Use Tables 6.2, 6.3 & 6.4

Calculation Sheet A - Noise from road traffic

Project Example E.3

Description

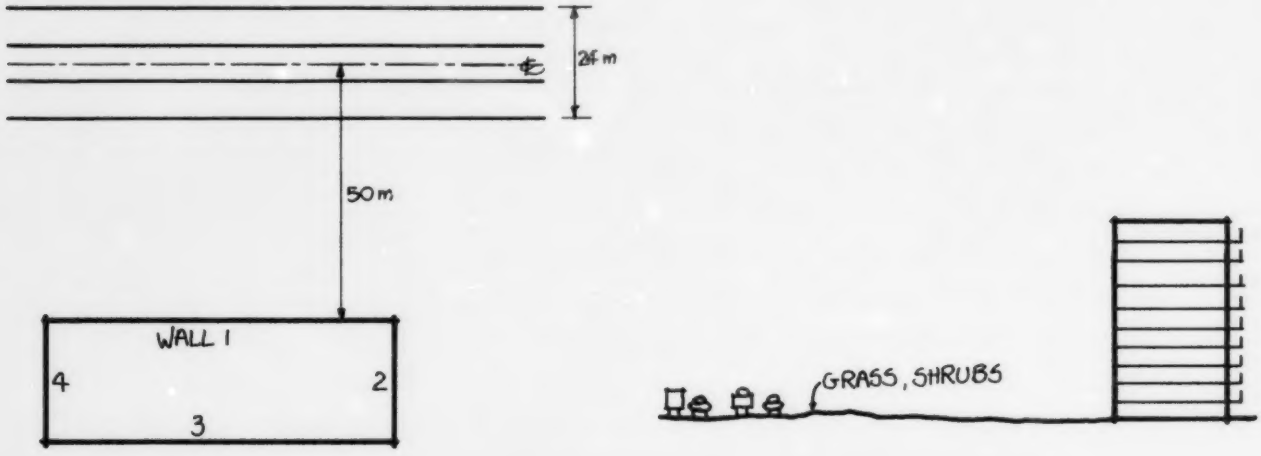
A 10-storey apartment block is proposed 50 m from a busy 4-lane divided highway

Proponent

Reference No.

Date:

Sketch



Daily traffic volume 96,000 vehicles 24 h

Percentage of heavy vehicles 10

Posted speed limit 90 km/h

Noise level at 30 m from centreline (Tables 3.1.3-3.1.8) 76 dB

Road gradient 0

Percentage of heavy vehicles 10

Correction to noise level for road gradient (Table 3.2) + 0 dB

Distance from intersection to receiver 200 m

Correction for interrupted flow (Table 3.3) + 0 dB

Percentage of heavy vehicles 10

Posted speed limit 90 km/h

Equivalent source height 0.6 m (Table 3.4)

Distance to building line 50 m

Ground surface hard _____ or soft _____

Effective total height 0.6 + 29 = 29.6 m (Figure 3a) Midpoint of 10th floor

15 at 29 m

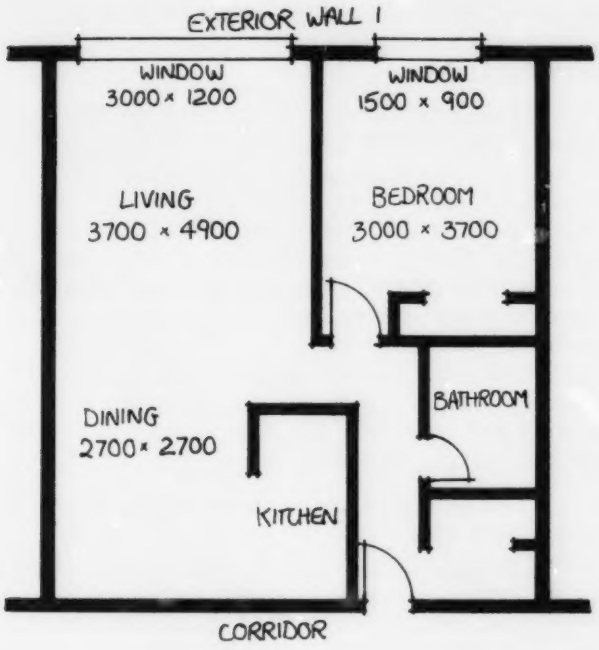
Correction for actual distance from centreline (Table 3.5) - 2 dB

Correction for a barrier (Calculation Sheet B) - 0 dB

Noise level reaching facade (Total of level and corrections) 74 dB

at 10th floor

Example E.3



ALL DIMENSIONS IN MILLIMETRES

Room type	Living/Dining		Bedroom	
Floor area (m^2)	25.4		11.1	
List of components of exterior wall	Wall (5.2 m^2) Window (3.7 m^2)		Wall (6.0 m^2) Window (1.4 m^2)	
Number of components	2		2	
Noise level at wall	74 B		74 B	
Required AIF (Table 5.1)	39		44	
Component	wall	window	wall	window
Percentage of floor area (Table 6.5)	20	16	50	12.5
Required construction (Tables 6.2, 6.3, 6.4)	EW2	3(63)3	EWZR	6(100)6 or 3(6)3(100)6

The calculation on the preceding page relates to the tenth floor of the building. The only steps in the procedure which depend on receiver height are the correction for a barrier (not applicable here) and the correction for distance from the centreline. The appropriate information and corrections for this example are listed below:

Floor No.	Effective Height	Total	Correction for distance	Noise Level at Wall 1
10	29.0 + 0.6 =	29.6	- 2 dB	74 dB
9	25.9 + 0.6 =	26.5	- 2 dB	74 dB
8	22.9 + 0.6 =	23.5	- 2 dB	74 dB
7	19.8 + 0.6 =	20.4	- 2 dB	74 dB
6	16.8 + 0.6 =	17.4	- 2 dB	74 dB
5	13.7 + 0.6 =	14.3	- 2 dB	74 dB
4	10.7 + 0.6 =	11.3	- 2 dB	74 dB
3	7.6 + 0.6 =	8.2	- 4 dB	72 dB
2	4.6 + 0.6 =	5.2	- 6 dB	70 dB
1	1.5 + 0.6 =	2.1	- 7 dB	69 dB

Note that the noise levels are highest at the upper floors because the "soft" ground surface has little effect on the noise reaching there. Similarly, if there were a barrier, it would provide less noise reduction at the upper floors than near the ground.

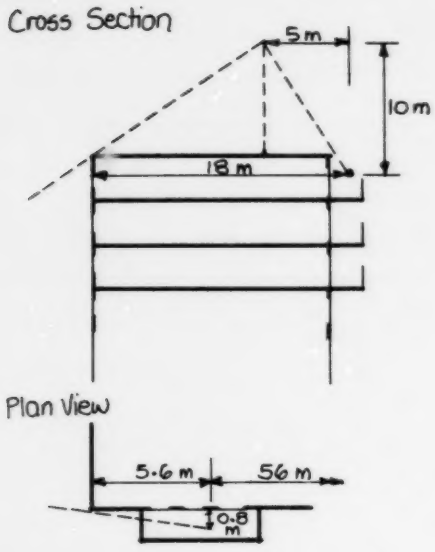
Because of this trend, the top floor of a project should be evaluated first to determine its acceptability (i.e., whether the outdoor noise level is below 75 dB).

If the apartment design is the same on all floors, then components meeting the AIF requirements for the top floor will also satisfy the requirements for all the lower floors. In this example the same component AIFs would be required for the fourth to tenth floors. For the first, second and third floors, the necessary AIF is lower, in accordance with the lower outdoor noise levels at these heights and appropriate components of lower AIF could be substituted.

The preceding example is a unit on the noisy side of the building (facing the highway). Balconies should not be included on this side, because the outdoor noise levels are unacceptably high. Acceptable indoor noise levels cannot be achieved with the windows open to provide ventilation; therefore, an alternate means of ventilation is required. Note that the addition of a storm window to the factory-sealed, double-glazed windows improves the thermal insulation, in addition to increasing the AIF.

For a large building such as this, the reduction in the noise level at the "sheltered" side (Wall 3) may exceed the 15 dB reduction allowed for detached housing. As is shown in the following calculation, the building in this example gives a barrier attenuation of at least 18 dB at the midpoint of the balconies on the sheltered side. This, together with the correction for the additional distance to this wall, results in noise levels of 55 dB or lower on the balconies. This outdoor noise level is acceptable, and no consideration of component AIF is required for this side of the building.

Caution: Treating the building as a barrier to determine the noise levels on the sheltered side is valid only if there are no additional buildings of comparable size nearby which could reflect sound back to the "sheltered" wall. If other buildings are present, the noise at the "sheltered" wall is taken to be 10 dB less than the level at the wall facing the traffic.



The barrier effect was calculated for the balcony with the smallest expected barrier attenuation: the top floor (and therefore the smallest barrier height relative to the receiver) and the balcony closest to one end of the building (the case most affected by noise coming around the end of the barrier). The receiver point (r) is taken to be 1.5 m above the midpoint of the balcony floor. As illustrated in Appendix B, the position of the top of the effective barrier formed by a building may be determined by using a scale drawing. Straight lines should be drawn from the receiver to the apparent top of the building as seen from those locations. The top of the effective barrier is where these lines meet. Only the portion of the drawing showing the top of the building is reproduced above. The effective barrier in this case is 5 m from the midpoint of the balcony and 10 m above the receiving point. The barrier attenuation calculation method in Appendix B shows that this barrier would provide an attenuation of 20 dB if no sound came around the end of the barrier.

From a scale drawing of the plan view of the barrier, the ratio v/g = 7 and the ratio u/g = 70 for the receiver at the midpoint of this balcony should be used. From Table 3.6 the effective barrier length ratio w = 8. Using this value in Table 3.7 gives a barrier attenuation of 18 dB, allowing for the noise coming around the end of the building.

Calculation Sheet A - Noise from road traffic

Project: Example E.4

Description:

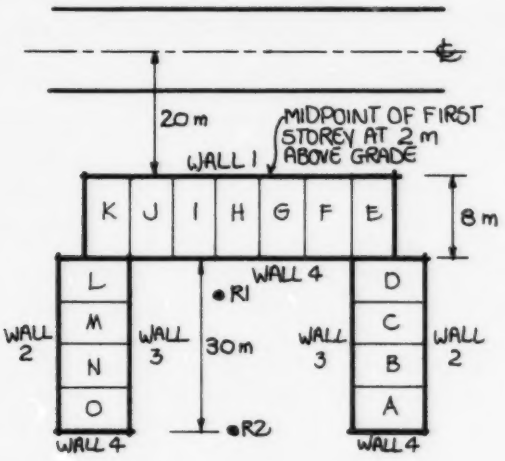
Proponent _____

Reference No. _____

Date: _____

Fourteen units of row housing are proposed near a 4-lane arterial road. The nearest units are 20 m from the centreline of the roadway: (12 m from the curb)

Sketch



Daily traffic volume 42,500 vehicles 24 h

Percentage of heavy vehicles 12

Posted speed limit 60 km/h

Noise level at 30 m from centreline (Tables 3.1.1-3.1.8) 69 dB

Road gradient N/A

Percentage of heavy vehicles 12

Correction to noise level for road gradient (Table 3.2) + 0 dB

Distance from intersection to receiver N/A m

Correction for interrupted flow (Table 3.3) + 0 dB

Percentage of heavy vehicles 12

Posted speed limit 60 km/h

Equivalent source height 1.0 m (Table 3.4)

Distance to building line 20 m

Ground surface hard ____ or soft ✓

Effective total height 1.0 + 2 = 3.0 m (Figure 3a)

Correction for actual distance from centreline (Table 3.5) + 1 dB

Correction for a barrier (Calculation Sheet B) - 0 dB

Noise level reaching facade (Total of level and corrections) 70 dB

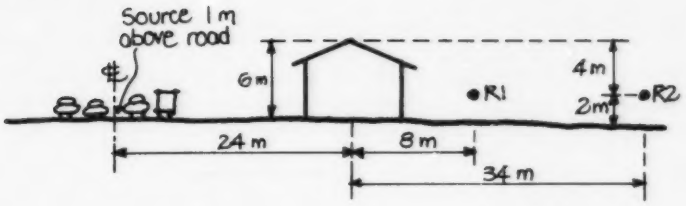
at 1st floor of wall 1

Calculation Sheet B - Barrier attenuation

at receiver R1

Reference No. E.4

Date: _____



This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-43

1. Distance a (source to barrier top)

Horizontal distance (f) is	24.00 m:	squared value =	576 m^2
Vertical distance (x) is	5.00 m:	squared value =	25 m^2
Sum of squared values is			601 m^2
Square root of sum is	24.51 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	8.00 m:	squared value =	64.0 m^2
Vertical distance (y) is	4.00 m:	squared value =	16.0 m^2
Sum of squared values is			80.0 m^2
Square root of sum is	8.94 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	32.00 m:	squared value =	1024.0 m^2
Vertical distance (z) is	1.00 m:	squared value =	1.0 m^2
Sum of squared values is			1025.0 m^2
Square root of sum is	32.02 m	= distance c	

4. Path length difference is a+b-c = 1.43 metres

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

Barrier to receiver distance (g) = _____ m
Length of barrier segment (u) = _____ m:)
Length of barrier segment (v) = _____ m:)

Effectively infinite for all positions in courtyard

From Table 3.6, effective barrier length ratio w = Infinite

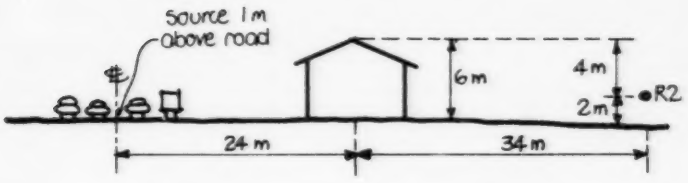
6. From Table 3.7, barrier attenuation = 15 dB

Calculation Sheet B - Barrier attenuation

at receiver R2

Reference No. E.4

Date: _____



This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

Horizontal distance (f) is	24.00 m:	squared value =	576 m^2
Vertical distance (x) is	5.00 m:	squared value =	25 m^2
Sum of squared values is			601 m^2
Square root of sum is	24.51 m	= distance a	

2. Distance b (barrier top to receiver)

Horizontal distance (g) is	34.00 m:	squared value =	1156 m^2
Vertical distance (y) is	4.00 m:	squared value =	16 m^2
Sum of squared values is			1172 m^2
Square root of sum is	34.23 m	= distance b	

3. Distance c (source to receiver)

Horizontal distance (f+g) is	58.00 m:	squared value =	3364 m^2
Vertical distance (z) is	1.00 m:	squared value =	1 m^2
Sum of squared values is			3365 m^2
Square root of sum is	58.01 m	= distance c	

4. Path length difference is a+b-c = 0.73 metres

(✓) Barrier interrupts line of sight
( ) Barrier does not interrupt line of sight

5. Plan view dimensions: (Effectively Infinite)

Barrier to receiver distance (g) = _____ m
Length of barrier segment (u) = _____ m:)
Length of barrier segment (v) = _____ m:)

Effectively Infinite

From Table 3.6, effective barrier length ratio w = Infinite

6. From Table 3.7, barrier attenuation = 13 dB.

Noise Levels in Courtyard Area

Example E.4

The preceding two pages give calculations of the effect of the row houses as a barrier for receiving positions R1 and R2 in the courtyard area.

Position	Noise Level At 30 m	Correction Due to Distance	Correction for Barrier	Noise Level
R1	69	0	- 15	54
R2	69	- 3	- 13	53

The resulting noise levels in the courtyard area are given in the table above; since these levels are below 55 dB, the entire courtyard area is satisfactory as outdoor amenity space.

For wall 1 of units E-K, the calculated noise level, as evaluated previously on Calculation Sheet A, is 69 dB + 1 dB (because actual distance is 20 m) = 70 dB.

At wall 2 of units A-E and K-O, the noise levels will be lower both because only half the road is visible (a 3 dB reduction as discussed in Part 5) and because of increasing distance from the road. For the midpoints of units E and K, the distance correction from Table 3.5 is 0 dB, so the resulting noise level is 69+0-3 = 66 dB. For units A and O (54 m from the centreline) the distance correction is -6 dB and the resulting noise level is 69-6-3 = 60 dB. Thus AIF calculations would be required for all the exterior wall 1 and wall 2 facades.

At all the wall 4 surfaces, the 15 dB reduction appropriate for the sheltered wall (as discussed in Part 5) would give a noise level of 55 dB or lower. At wall 3 of units A-D and L-O, the -3 dB correction for side walls (as discussed in Part 5) together with the barrier and distance corrections (such as those for positions R1 and R2) reduce the noise level below 55 dB, even for the upper storey, for which the barrier correction would be only -11 dB. Thus no AIF calculations would be required for these facades, and open windows would be an acceptable means of ventilation.

Appendix F

Blank Calculation Sheet

Calculation Sheet A - Noise from road traffic

Description:

Sketch

Project _____

Proponent _____

Reference No. _____

Date: _____

Daily traffic volume _____ vehicles 24 h

Percentage of heavy vehicles _____

Posted speed limit _____ km/h

Noise level at 30 m from centreline (Tables 3.1.1-3.1.8) _____ dB

Road gradient _____

Percentage of heavy vehicles _____

Correction to noise level for road gradient (Table 3.2) + _____ dB

Distance from intersection to receiver _____ m

Correction for interrupted flow (Table 3.3) + _____ dB

Percentage of heavy vehicles _____

Posted speed limit _____ km/h

Equivalent source height _____ m (Table 3.4)

Distance to building line _____ m

Ground surface hard _____ or soft _____

Effective total height _____ m (Figure 3a)

Correction for actual distance from centreline (Table 3.5) _____ dB

Correction for a barrier (Calculation Sheet B) _____ dB

Noise level reaching facade (Total of level and corrections) _____ dB

Calculation Sheet B - Barrier attenuation

Reference No. _____

Date: _____

This worksheet is to be used with reference to Figures 3b-3e or Figures 4b-4e

1. Distance a (source to barrier top)

   Horizontal distance (f) is _____ m: squared value = _____ m^2
   Vertical distance (x) is _____ m: squared value = _____ m^2
   Sum of squared values is _____ m^2
   Square root of sum is _____ m = distance a

2. Distance b (barrier top to receiver)

   Horizontal distance (g) is _____ m: squared value = _____ m^2
   Vertical distance (y) is _____ m: squared value = _____ m^2
   Sum of squared values is _____ m^2
   Square root of sum is _____ m = distance b

3. Distance c (source to receiver)

   Horizontal distance (f+g) is _____ m: squared value = _____ m^2
   Vertical distance (z) is _____ m: squared value = _____ m^2
   Sum of squared values is _____ m^2
   Square root of sum is _____ m = distance c

4. Path length difference is a+b-c = _____ metres

   ( ) Barrier interrupts line of sight
   ( ) Barrier does not interrupt line of sight

5. Plan view dimensions:

   Barrier to receiver distance (g) = _____ m
   Length of barrier segment (u) = _____ m:) ratio u/g = _____
   Length of barrier segment (v) = _____ m:) ratio v/g = _____

   From Table 3.6, effective barrier length ratio w = _____

6. From Table 3.7, barrier attenuation = _____ dB.

Calculation Sheet C1 - Railway engine noise

Reference No. _____

Date: _____

Necessary information for average 24-hour period for each track

Typical train speed	_____	km/h
Average total number of diesel locomotives	_____	
Average total number of self-powered electric cars	_____	
Average total number of railway cars	_____	
Average number of trains	_____	

Average total number of locomotives (D)	_____		
Average total number of railway cars (n)	_____		
Average number of cars/locomotives (n/D)	_____		
Noise level at 30 m for train speed 80 km/h (Table 4.1)			_____ dB
Typical train speed	_____	km/h	
Correction for typical train speed (Table 4.2)			_____ dB
Distance from source to receiving point	_____	m	
Effective total height above ground, using a source height of 4 m	_____	m	
Ground surface. Hard _____ Soft _____			
Correction for horizontal distance (Table 4.4)			_____ dB
Barrier attenuation, if applicable, using source height of 4 m	_____	dB	
Correction for barrier (minus barrier attenuation)			_____ dB
Total engine noise level			_____ dB

Calculation Sheet C2 - Wheel-rail noise

Reference No. _____

Date: _____

Average total number of railway cars	_____	
Average total number of self-powered electric cars multiplied by two	_____	
Average total number of cars	_____	
Typical train speed	_____ km/h	
Noise level at 30 m (Table 4.3)		_____ dB
Distance from source to receiving point	_____ m	
Effective total height above ground, using a source height of 0.5 m	_____ m	
Ground surface. Hard _____ Soft _____		
Correction for horizontal distance (Table 4.4)		_____ dB
Barrier attenuation, if applicable, using source height of 0.5 m	_____ dB	
Correction for barrier (minus barrier attenuation)		_____ dB
Total wheel-rail noise		_____ dB

Calculation Sheet C3 - Whistle noise

Reference No. _____

Date: _____

Shortest distance to track	_____ m		
Distance along track to warning point	_____ m		
Whistle noise for single train a: 80 km/h (Table 4.5)	_____ dB		
Average number of trains each day	_____		
Typical speed of train	_____ km/h		
Correction for number of trains and typical speed (Table 4.7)		0	dB
Ground surface. Hard _____ Soft _____			
Shortest distance to warning zone	_____ m		
Effective total height above ground, using a source height of 4 m	_____ m		
If ground is hard, there is no correction		_____	dB
If ground is soft, correction for ground attenuation (Table 4.6)		_____	dB
Barrier attenuation if applicable, using a source height of 4 m (N.B. This calculation is modified slightly, see page 43 of text)	_____ dB		
Correction for barrier (minus barrier attenuation)		_____	dB
Total whistle noise		_____	dB
The levels must be combined using Table 5.1			
Total engine noise	_____ dB		
Total wheel-rail noise	_____ dB		
Combined noise	_____ dB		
Total whistle noise	_____ dB		
Total combined noise level from railway		_____	dB

N.B. This procedure must be followed for each track. The individual tracks are then combined using the same procedure.

Calculation Sheet D - Sound insulation needs

Reference No. _____

Step 1 - Combine noise levels (See Section 5)

Date: _____

	Wall 1	Wall 2	Wall 3	Wall 4
Noise level from				
Source 1				
Source 2				
Source 3				
Source 4				
Source 5				
Combined level				

Use Table 5.1

Step 2 - Find number of components (ignore if level at wall under 55 dB)

Room	Wall 1			Wall 2			Wall 3			Wall 4			Total number of components
	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	

Step 3 - Find required AIF

Use Table 6.1 and number of components found above

Calculation Sheet E - Selection of components Reference No. _____

Step 1 - Enter component area Date: _____
(Only components of exterior walls are to be included in the calculations)

Room	Wall 1			Wall 2			Wall 3			Wall 4			Room Floor Area
	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	Window	Wall	Door	

Step 2 - Find component percentages (Use values from Step 1)

Use Table 6.5

Step 3 - Select components (Component % from Step 2, and AIF values from Step 3 on Sheet D)

Use Tables 6.2, 6.3 & 6.4

Worksheet for AIF Calculations

Frequency	A-weighted Source Sound Pressure Level (dB)	Sound Transmission Loss (dB)	A-weighted Indoor Sound Pressure Level (dB)	Energy Equivalent of Indoor (SPL)
	(A)	(B)	(C = A-B)	(D = antilog (C/10))
100	47			
125	53			
160	58			
200	61			
250	63			
315	65			
400	67			
500	68			
630	69			
800	70			
1000	70			
1250	70			
1600	70			
2000	70			
2500	70			
3150	69			
4000	68			
5000	66			
	Sum of values in column D is E =			

Calculated indoor A-weighted sound level: $10 \log_{10}(E) =$ ____ = FAIF
(component area = 80% of floor area): (77-F) = ____ = G

Component Area as a Percentage of Room Floor Area	Acoustic Insulation Factor (AIF)
6.3	(G+11 =
8	(G+10) =
10	(G+ 9) =
12.5	(G+ 8) =
16	(G+ 7) =
20	(G+ 6) =
25	(G+ 5) =
32	(G+ 4) =
40	(G+ 3) =
50	(G+ 2) =
63	(G+ 1) =
80	(G) =
100	(G - 1) =
125	(G - 2) =
160	(G - 3) =

GLOSSARY OF TECHNICAL TERMS

This glossary is designed to provide the necessary definitions of terms in as simple a way as possible.

A-Weighted Sound Level:

The sound level as measured on a sound level meter, using a setting that emphasizes the middle frequency components similar to the response of the human ear. The A-weighted sound level is found to correlate well with subjective assessments of the annoying or disturbing effects of sounds.

Ambient Noise Level:

The sound level of background noise characteristic of an environment. Practically, the level of a specific added sound must be above the ambient noise level in order to be perceived.

Attenuation:

A reduction in sound level in travelling from a source to a receiving point.

Barrier:

A solid physical obstruction between the roadway/railway and the observer, which interrupts the line of sight between them.

Barrier Attenuation:

The reduction in level of sound travelling over hard ground resulting from a barrier between source and receiving point.

Berm:

A mound of earth that interrupts the line of sight between a source and a receiving point, thus acting as a barrier.

Decibel (dB):

(See Sound Level)

Equivalent Level (L_{eq}):

The level of a steady sound carrying the same energy at a given time as the fluctuating sound. For the purposes of these guidelines, L_{eq} is the value over a 24-hour period.

Gradients:

The slope of a roadway/railway expressed as the ratio of the increase in height to the distance along the roadway/railway, and then converted to a percentage.

Ground Attenuation:

The reduction in level of sound travelling close to the ground. Over hard ground, the ground attenuation is zero.

Heavy Vehicles:

For the purpose of these guidelines, all road vehicles with more than four wheels are classified as heavy vehicles.

Noise:

Sounds other than a specifically desired sound. (See also Ambient Noise Level.) In these guidelines, the sounds of road and rail traffic are taken to be noises.

Noise Level:

For the purposes of this document, the noise level is the A-weighted, 24-hour equivalent sound level.

Propagation:

The passage of sound from a source to a particular receiving point.

Receiver Height:

Taken as 1.5 m above the floor, and measured relative to ground level.

Receiving Point:

In these guidelines, a location at which the noise level is to be determined.

Sound Level:

A measurement of sound obtained by comparing it with a standard reference sound; in practice, the reading on a sound level meter. The level is expressed in decibels.

Source:

A general term used to indicate road or rail traffic as a source of noise.

Source Height:

The effective height of the noise source above the roadway or the railway track. The National Research Council has assigned the following values: 0.5 m for railway wheel noise, 4 m for locomotive noise, and road traffic source height varying with traffic mix and speed (See Table 3.4).

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